# NAVAL POSTGRADUATE SCHOOL
# Monterey, California

# THESIS

## SLEEP PATTERNS IN U.S. NAVY RECRUITS: AN ASSESSMENT OF THE IMPACT OF CHANGING SLEEP REGIMENS

by

Brian R. Baldus

September 2002

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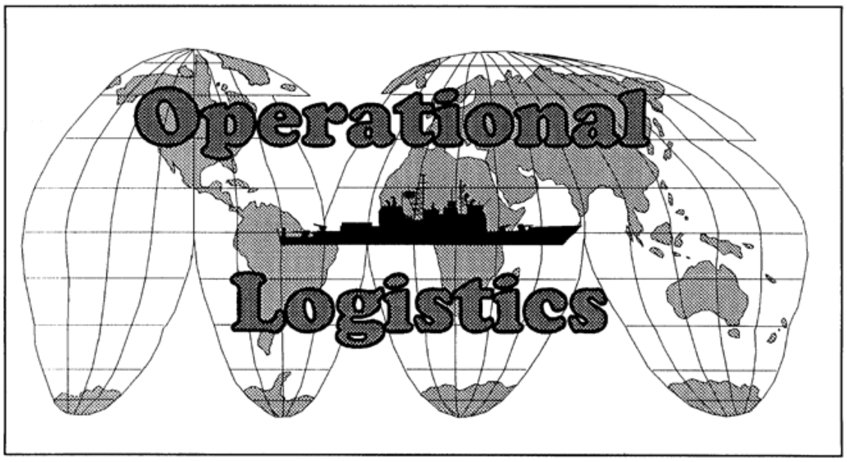
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The U.S. Navy Recruit Training Command in Great Lakes, Illinois is responsible for training all enlisted personnel, about 50,000 young recruits per year. Demands on these recruits are steep and there is concern that by restricting the amount of sleep, learning efficiency is adversely affected. There are additional concerns about possible increases in attrition and reductions in morale due to sleep deprivation. Every minute of the 63 day training schedule is closely managed, including the time allocated for sleep. Within recent years, the designated sleep regimens have changed considerably from 6 hours of sleep (2200 to 0400) in 2001 to 8 hours of sleep (2200 to 0600) as of June 2002. In the months of April through June, 2002, we collected data on the quantity and quality of sleep received by 31 volunteer recruits in two 8 hour conditions: 2100 to 0500 and 2200 to 0600. Using wrist activity monitors, we calculated the actual amount of sleep and contrasted it with the expected amount for each participant. Additionally, comparisons were made between bedtimes (2100 vs. 2200), gender, different training divisions, nights with and without sleep disruptions (due to watch standing and other factors), and different days of the week.

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# SLEEP PATTERNS IN U.S. NAVY RECRUITS: AN ASSESSMENT OF THE IMPACT OF CHANGING SLEEP REGIMENS

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requirements for the degree of

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# ABSTRACT

The U.S. Navy Recruit Training Command in Great Lakes, Illinois is responsible for training all enlisted personnel, about 50,000 young recruits per year. Demands on these recruits are steep and there is concern that by restricting the amount of sleep, learning efficiency is adversely affected. There are additional concerns about possible increases in attrition and reductions in morale due to sleep deprivation. Every minute of the 63 day training schedule is closely managed, including the time allocated for sleep. Within recent years, the designated sleep regimens have changed considerably from 6 hours of sleep (2200 to 0400) in 2001 to 8 hours of sleep (2200 to 0600) as of June 2002. In the months of April through June, 2002, we collected data on the quantity and quality of sleep received by 31 volunteer recruits in two 8 hour conditions: 2100 to 0500 and 2200 to 0600. Using wrist activity monitors, we calculated the actual amount of sleep and contrasted it with the expected amount for each participant. Additionally, comparisons were made between bedtimes (2100 vs. 2200), gender, different training divisions, nights with and without sleep disruptions (due to watch standing and other factors), and different days of the week.

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# EXECUTIVE SUMMARY

United States Navy recruits are trained at the Recruit Training Command (RTC) in Great Lakes, Illinois. Basic training, or Boot Camp, lasts approximately 63 days and encompasses many areas of military training. The schedules of the recruits are closely managed, and this includes the time allocated for their sleep. As recently as 2001, recruits were scheduled to sleep for only 6 hours per night (from 2200 to 0400). This sleep regimen changed in May 2002 to 8 hours, for a sleep schedule of 2100 to 0500. Currently, U.S. Navy recruits are scheduled to sleep for 8 hours from 2200 to 0600.

This thesis assessed the quantity and quality of sleep received by a sample of recruits in two 8-hour sleep conditions: 2100 to 0500 and 2200 to 0600. The data represent a cohort of recruits who shifted bedtimes from 2100 to 2200 during Boot Camp. This research involved the analysis of sleep patterns and activity levels collected by wrist activity monitors. The data collection occurred from April to June 2002, comprising one complete cycle of recruit initial training.

The results showed that the majority of recruits received more sleep when following the 2200 to 0600 sleep regimen than when following the 2100 to 0500 sleep regimen. On average, the 2200 bedtime resulted in 22 more minutes of sleep per night per recruit. This finding coincides with the predictable shift in young adult circadian rhythms, which favors later bedtimes.

On average, recruits that have a disrupted night of sleep get 320.8 minutes of sleep, versus 428.3 minutes for a non-disrupted night, a difference of 107.5 minutes. Recruits received the most sleep on Friday nights and the least sleep on Saturday nights, receiving 391.0 and 352.9 minutes of sleep, respectively. Division 219 received the most sleep, averaging 404.2 minutes per night, while division 224 received the least, averaging only 346.7 minutes of sleep per night.

Although not statistically significant, the results suggest a difference in sleep patterns between genders. Over the course of the study, female recruits received 10 more minutes of sleep on average than did their male counterparts (374.1 minutes vs. 364.5

minutes, respectively). During nights of non-disrupted sleep, females received 10 more minutes of sleep (434.4 minutes vs. 424.3 minutes). On nights with sleep disruptions, females received 18 more minutes of sleep (331.0 minutes vs.312.8 minutes).

The primary objective of this study was to determine if there were differences between the quantity and quality of sleep between 2100 and 2200 bedtimes in these young Navy recruits. From our results, we conclude that the change in bedtime from 2100 to 2200 was indeed beneficial and should remain in place. Further studies are recommended to determine the optimal sleep regimen for recruits.

# I. INTRODUCTION

## A. OVERVIEW

United States Navy recruits are trained at the Recruit Training Command (RTC) in Great Lakes, Illinois. Basic training, or Boot Camp, lasts approximately 63 days and encompasses many areas of military training. The schedules of the recruits are closely managed, and this includes the time allocated for their sleep. Within recent years, the designated sleep amounts and bed times for recruits have changed considerably. As recently as 2001, recruits were allowed to sleep for only six hours per night from 2200 to 0400. This sleep regime changed in December 2001 to seven hours (from 2100 to 0500) and then again in May 2002 to eight hours, for a sleep schedule of 2100 to 0500. Currently, U.S. Navy recruits are allowed to sleep for eight hours from 2200 to 0600.

This thesis will assess the amount and quality of sleep received by recruits in these two 8 hour conditions: 2100 to 0500 and 2200 to 0600. An examination of the sleep activity levels (as measured by actigraphy data) shows how much sleep recruits actually receive versus what they are expected to get. This thesis also examines two sleep regimes (2100 to 0500 and 2200 to 0600) to determine if recruit sleep differs due to bedtime. Additionally, comparisons are made between male and female recruits, recruits of different training divisions, sleep amounts during watch standing nights and comparisons between sleep levels on different days of the week.

## B. BACKGROUND

It is well known that fatigue is a leading contributor to accidents and degraded performance (Dawson and Reid, 1997). Fatigue in the U.S. Navy is very common due to high operational tempos, demanding work schedules and ever-increasing requirements to do more learning and retention of new data with less. Excessive fatigue due to inadequate sleep can result in students losing up to 30% of the material learned within two days (Munson, 2000). Learning effectiveness is a major concern for the U.S. Navy Recruit Training Command, which trains about 50,000 young recruits per year. Educational demands on these recruits are steep and there is concern that by restricting the amount of sleep, learning efficiency is adversely affected. There are additional concerns about possible increases in attrition and reductions in morale due to sleep deprivation.

## C. OVERVIEW OF THESIS

This thesis analyzes the quantity and quality of sleep of U.S. Navy recruits in Great Lakes, Illinois. It is based on a study in which actigraph data were obtained from 20 male and 11 female recruits from five different training divisions, during one 63-day session of Boot Camp. Of the initial 35 recruits participating in the study, 31 recruits had usable data. The average age for all recruits in Boot Camp during this time period was 21.0 years old. The average age of recruits for this study was 21.3 years old. The recruits were sampled from five different divisions: 216, 217, 218, 219, and 224. Divisions 216 and 219 were male only divisions, whereas divisions 217, 218 and 224 were mixed gender divisions.

Chapter II provides a literature review of related topics about sleep research, young adults, fatigue issues, and the unique attitude toward sleep held by the military. The methodology of the thesis, including a detailed description of actigraphy data and how it is processed, is presented in Chapter III. The analytical strategy and statistical results are in Chapter IV. Finally, Chapter V offers conclusions and recommendations for future work. Appendices provide graphical displays of the actual data used for analysis.

# II. LITERATURE REVIEW

## A. OVERVIEW

The field of sleep and fatigue has been studied extensively. This chapter will present an overview of the current literature and salient research concepts necessary to understand patterns of human sleep. Specifically, concepts to be introduced include normal sleep patterns in humans, specific differences in the sleep patterns of adolescent and young adults, an overview of circadian rhythms, and a conceptual model of sleep, fatigue, and human performance (SAFTEtm). Additionally, the unique view of sleep and wakefulness that has traditionally been held by members of the military will be discussed.

## B. NORMAL SLEEP PATTERNS IN HUMANS

Human adults experience five stages of sleep during a typical night's sleep: stages one through four and REM (Rapid Eye Movement) sleep. Stages one through four are collectively referred to as Non-REM (NREM) sleep. Each stage has its own identifying marks as measured by electroencephalographs (EEGs), electromyograms (EMGs), and electrooculograms (EOGs). EEGs measure brain waves via electrodes pasted to the scalp. EMGs measure muscle activity and EOGs measure eye movements and also use skin or contact electrodes (Chudler, 2002). A complete sleep cycle consists of all five stages of sleep (see figure 1). In the first stage of sleep, the body begins to

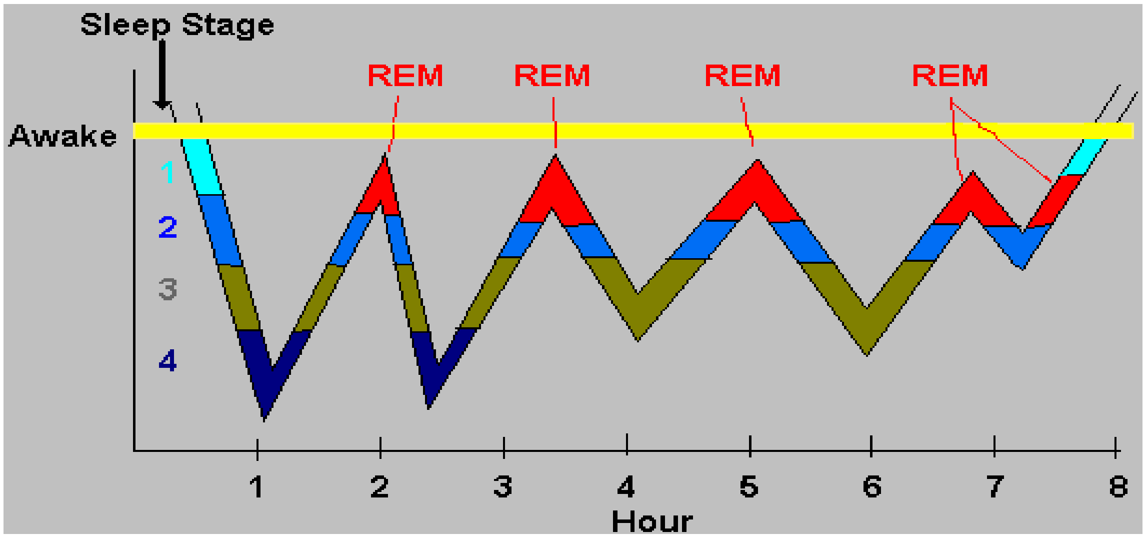


Figure 1. Common Pattern of Sleep Architecture in Humans (From: Chudler, 2002)

relax and starts to fall asleep. Body temperature falls, and brain activity is minimal. Drifting in and out of wakefulness is common. A non sleep-deprived adult takes 15-20 minutes to fall asleep. Stage two sleep generally serves as a transitional phase from stage one sleep into stages three and four. The body continues to cool down, heart rate, breathing, and brain activity slows as well. Stages three and four sleep are considered deep sleep stages and are characterized by large, slow brain waves. It is hardest to awaken or to be awakened in these stages. Sleep-deprived individuals will enter stages three and four sleep immediately, skipping stages one and two, in order to catch up on sleep and eliminate their sleep debt. The final stage of sleep is REM sleep, characterized by the rapid movement of the eyes. The body stays motionless while the eyes flutter. Heart rate, blood pressure and brain activity all increase. Dreams are most often seen in REM sleep and are better remembered if awakened during this stage (Kantrowitz, et al., 2002).

In humans, the requirements for sleep change throughout the lifespan. As infants, we sleep in shorter blocks of time, from one to three hours, many times per day, for a total of approximately sixteen hours. By one year of age, the duration of sleep gets longer with fewer intervals, with nighttime and daytime sleep totaling roughly 13 to 14 hours. Around four or five years of age, the number of sleep episodes per day decreases to one long nighttime sleep and usually one nap per day, totaling approximately 12 hours (Chudler, 2002). Older children require 10 hours of sleep (Dement, 2002) while estimates for required hours of sleep for teenagers vary but usually suggest at least nine hours (BRAIN, 2002) but sometimes more than nine and a quarter hours (Spinks, 2002). The American Heritage dictionary defines adolescence as ‘a transitional period of development between youth and maturity,’ and an adolescent as someone undergoing adolescence, ‘especially a teenager.’ Sleep researchers commonly consider someone to be an adolescent between the ages of 11 and 22 (Dement, 2002). Some researchers include adolescents and young adults between the ages of 12 to 25 years old in one group (Carskadon, 2000).

During the adolescent years, our requirement for sleep may stay constant, but our actual sleep quantities vary widely from day to day. Sleep on weekdays often results in less than eight hours of sleep, falling well below the recommended amount, while the weekends are used as 'catch-up' days to replenish a sleep deficit accrued throughout the week. Catch-up sleep is good up to a point. If someone usually wakes up between seven and nine in the morning during weekdays and then sleeps in past noon on the weekends, they send a message to shift their body's circadian rhythm. Just as the body begins to adjust to this later sleep pattern, the weekend ends. When Monday morning arrives, their body is not ready to wake up for a few more hours. This compounds the sleep deficit and sets them into a 'jet-lag' type of feeling, causing drowsiness and other consequences in poor sleep patterns (Carskadon, 2000).

Many adults are sleep deprived due to multiple factors including ignorance about good sleep behaviors and a culture that promotes working long hours. With greater demands placed on the average worker, their work day is extended. The need to return to work early the next morning does not allow us to replenish our sleep deficit and thus we become sleep deprived. When people are in a state of sleep deprivation, they do not perform as well as when they are fully rested. Sleep helps restore our mental energy for the next day's work. It affects our personalities and our sense of humor. Lack of sleep affects our thinking and makes us more likely to make errors. Lack of sleep also affects us physically, degrading our coordination and agility (Kavey, 2002).

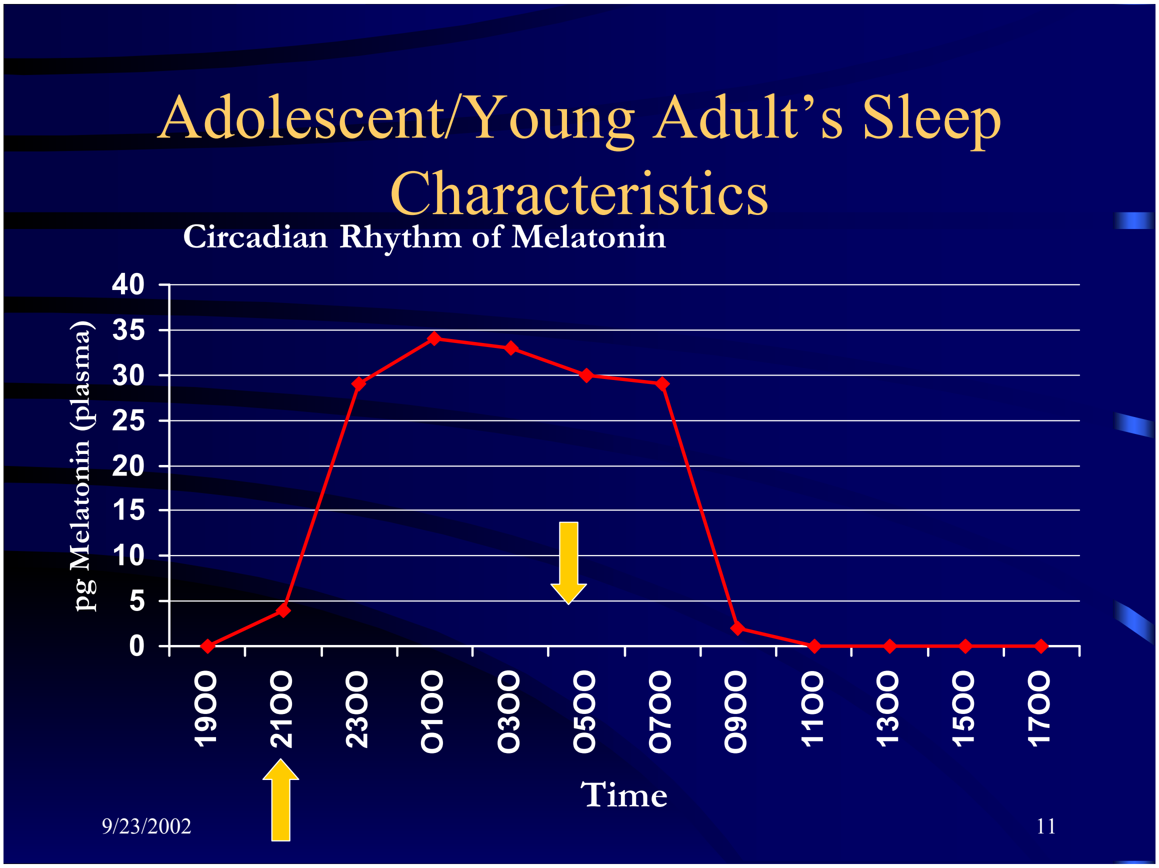
In our later years, we revert back to sleeping for shorter durations but more sleep episodes per day. Older adults generally need as much sleep as they did in early adulthood. People over the age of 65 are likely to develop sleep problems such as sleep apnea and insomnia. These changes in sleep patterns for the elderly may be a natural change in the circadian rhythms or it may be as a result of other age-related illnesses (BRAIN, 2002).

## C. ADOLESCENT SLEEP PATTERNS

Adolescent sleep needs are different from adults in numerous ways. Their lives are considerably different, with different social demands, part-time jobs, sports activities and schoolwork at the high school or college level. Their desire to establish their independence from their parents may also influence their decisions on bedtimes and may cause challenging relationships between the child and the parent. These personal issues and activities often result in later bedtimes, yet they still have to awake at the same time for school. However, teens may not be simply rebelling or trying to establish their independence by staying up later and later at night. Studies have shown that the secretion of melatonin occurs about an hour later in older adolescents. In younger adolescents, melatonin induces sleep around 9:30 p.m., but in older adolescents, this happens around 10:30 p.m. ("The Sleepy Teen Phenomenon," 2000). In other studies, it has been shown that an adolescent's natural bedtime is 11 p.m. We know that adolescents require at least as much sleep as they did as pre-adolescents and we have also observed that daytime sleepiness increases in adolescents. This happens even when an optimal sleep schedule can be maintained. Adolescent's sleep patterns undergo a phase delay that promotes going to bed at later times and waking up later in the morning (Carskadon, 2000). Other research has found that the sleep wake cycle in adolescents is shifted, favoring later bedtimes and later wake times (Graham, 2000). Mary Carskadon, a leader in adolescent sleep research, suggests that the biological clock of an adolescent may shift forward and create a 'forbidden zone' around 9:00 or 10:00 at night where they cannot sleep even if they want to (Spinks, 2002). Sleep deprivation in adolescents can result not only in daytime sleepiness but also in sour mood states and even depression. The combination of extra social demands, early morning school schedules and peer pressures create sleep-deprived adolescents that may have difficulties learning or adapting to their new social responsibilities (Carskadon, 1994).

## D. CIRCADIAN RHYTHMS

Circadian rhythms refer to biological rhythms with approximately 24 hour cycles. The term circadian is Latin for "around a day," with *circa* meaning 'about' and *dies* meaning 'day.' The terms ultradian and infradian rhythms refer to biological rhythms of more than a day and less than a day, respectively. This biological clock is the brain mechanism that determines when periods of increased and decreased activity occur in various biological systems. The biological clock in humans is regulated by the suprachiasmatic nucleus, or SCN, that contains about 20,000 neurons that send signals throughout the body. The SCN is located in the brain in the hypothalamus. When light reaches the retina, the SCN signals the pineal gland to suppress the release of melatonin. Melatonin is the naturally occurring hormone that causes a person to feel sleepy. It is produced by the pineal gland and is released during periods of darkness (BRAIN, 2002).



Adolescent/Young Adult's Sleep Characteristics

Circadian Rhythm of Melatonin

9/23/2002

11

Figure 2. Circadian Rhythm of Melatonin

The circadian rhythm in humans has been found to be around 25 hours. However, there are enough social clues in our world that allow us to reset our biological clocks to follow the 24 hour day. These external clues are called zeitgebers, German for 'time givers.' Zeitgebers are such things as an alarm clock, the timing of your meals, hearing someone say 'good morning' to you or any other regular event that you associate with a specific time of day (BRAIN, 2002).

The circadian rhythm has two peaks and two troughs throughout the normal 24-hour day. The peak in alertness usually happens around 9:00 or 10:00 in the morning and similarly at 9:00 or 10:00 at night. Adolescents are energized and active at 10:00 or even 11:00 at night (Carskadon, 2000), approximately the same time that an adult's circadian rhythm begins to drop. The lowest point of alertness happens around four in the morning and a lesser low point in the afternoon around three or four o'clock. Afternoon sleepiness that is often equated with post-lunch factors is actually not a result of eating a large heavy lunch. While the meal may be an aggravating factor, this feeling of sleepiness is the body reaching a low point in the circadian rhythm (LeClair, 2001).

Our circadian rhythm controls more than just our sleep-wake cycles. Other factors affected are our body's core temperature, urine production, blood pressure, hormone production, digestion, heart attack and stroke occurrences, asthma attacks, migraine headache attacks and even respiratory allergy symptoms.

## E. THE NEED FOR SLEEP

Sleep is a process that restores the body's energy supplies that have been depleted through the day's activities. The body does most of its repair during sleep. Muscle tissue is rebuilt and restored and much of the human growth hormone (HGH) is produced. Sleep improves muscle tone and skin appearance. The body's immune system behaves less effectively when sleep deprived. Sleep is also a time for restoring mental energy. In fact, sleep can help learning since memory consolidation actually continues to take place while asleep (Spinks, 2002). In the past, it has been thought that sleeping is a time of rest for the brain, too. Now, however, scientists believe that parts of the brain are just as active during sleep as it is when the body is awake. In fact, to maintain a state of sleep, special nerve cells must be active (Saper, 1996).

### 1. Learning

The ability to learn and retain information is reduced when someone is sleep deprived. With an average amount of sleep per night (usually eight hours) an individual can perform tasks well and learn at a normal pace. In a study by Graham (2000), subjects continually performed better at assigned tasks with eight hours of sleep per night. In the same study, the learning curve dropped dramatically for subjects getting six hours of sleep. In subjects getting only four hours of sleep, tasks performed became worse (Graham, 2000). Experiments performed at Harvard Medical School showed improvement in learning when sleeping after the learning occurred. A battery of tests was given to students and then they were allowed to sleep for various amounts of time. The results showed that the brain consolidates and practices what is learned during the day and learning actually takes place while a person is sleeping (Spinks, 2002).

### 2. Driving Safety

Sleepiness and blood alcohol content (BAC) levels have been compared many times. In some studies, sleepiness has been linked to as much as 42% of automobile fatalities. It has also been shown that after 19 hours of sleep deprivation, subjects have shown performance that is consistent with a BAC level of .05% and after 24 hours of sleep deprivation, a .10% BAC (Arnedt, et al., 2001).

Young adult males are at the highest risk for car accidents. Adding fatigue or sleep deprivation only compounds the matter. Over 100,000 traffic crashes are attributed to drowsiness or fatigue each year. A North Carolina study found that drivers under the age of 25 years old cause 55% of traffic accidents that are attributed to drowsy driving. The peak age of these drivers was 20 years old (Carskadon, 2000). Numbers of crashes have followed the circadian rhythm of humans as figure 3 shows. Most accidents happen early in the morning. The numbers begin to rise in the late evening, at the point when most motorists have been up all day. The numbers continue to rise through the late hours

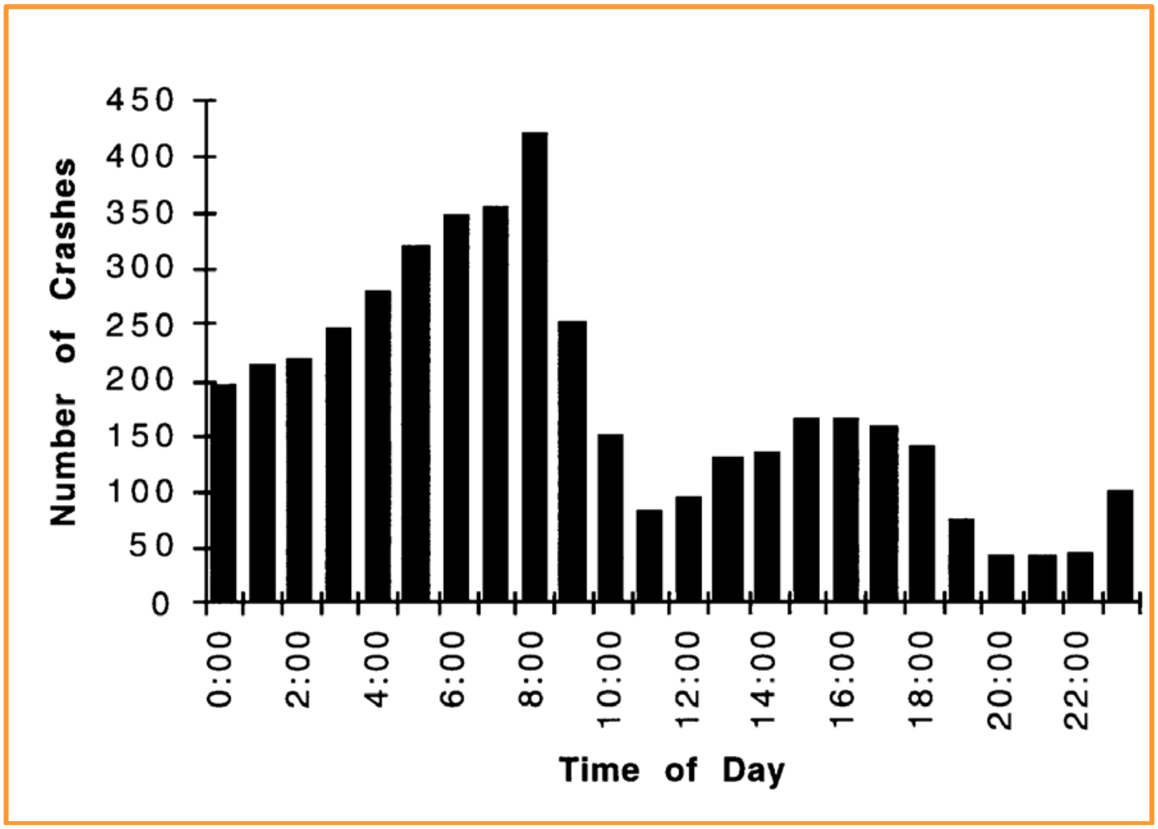


Figure 3. Number of Vehicle Accidents Relative to Time of Day (From: Rosen, 2002)

of the morning, hours we know to be the lowest points in alertness according to our circadian rhythms. There is also a secondary peak in accidents in the afternoon, another known peak in our circadian rhythms. (Arnedt, et al., 2001)

Fatigue has contributed to many high-profile accidents in recent times, including the Exxon Valdez grounding, and the Chernobyl and Three Mile Island nuclear accidents (Business Wire, 1999). It is also interesting that all of these accidents happened on the midnight shift, when workers are the most fatigued (Carskadon, 1994).

### 3. The Sleep, Activity, and Fatigue, Task Effectiveness Model

Efforts to model human performance and fatigue have been around for decades. One model was proposed in 1989 by Terry Klopsic. In 1993, Dr. Steve Hursh published modifications to that sleep model into that would later become the Sleep Performance Model (SPM) in 1996. Since then, Dr. Hursh has modified the model, now called SAFTE, the Sleep, Activity, and Fatigue, Task Effectiveness model, to suit the needs of various activities, including the military and specifically the U.S. Air Force. SAFTE incorporates one's circadian process and calculates such things as sleep debt, sleep reservoir, sleep quality and sleep quantity. It uses this information to calculate one's predicted effectiveness, then graphically displays it using FAST. Both the SAFTE algorithm and the FAST computer model are discussed in the next chapter. SAFTE's primary capability is that it can predict one's efficiency from actigraphy data.

## F. INDICATIONS OF SLEEP DEPRIVATION

The only way to cure sleep deprivation is to go to sleep. If that is not possible, one should be aware of the signs that they are sleep deprived and then make a serious effort to obtain the necessary sleep. The following is a partial list of characteristics that can help in determining whether a person is getting an adequate level of sleep: needing an alarm clock at all instead of waking up naturally; struggling to get out of bed in the morning; feeling tired during the week; sleeping or napping in the middle of the day; trouble concentrating; trouble remembering; needing more and more caffeine; slow with critical thinking, problem solving or creative thinking; falling asleep watching TV; falling asleep after heavy meals or low doses of alcohol; feeling drowsy while driving; and sleeping extra on weekends (Maas, 1998). Suffering from any one of these symptoms is an indication of sleep deprivation.

## G. CONSEQUENCES OF SLEEP DEPRIVATION

The consequences of sleep deprivation range from minor incidents to death. Traffic accidents increase with drowsy drivers, learning rate is slowed, students receive lower grades, short-term memory is reduced and one can have inconsistent logical reasoning skills. Decreased vigilance and a negative mood (depressive symptoms) are quite common. The body has a decreased immunity level, increases the production of stress hormones and is likely to demand an increase use of stimulants, such as caffeine to stay awake and alert. Finally, an increased risk of unintentional injury and death results since our attention level is decreased (Carskadon, 2000).

## H. FATIGUE COUNTERMEASURES

The best way to fight fatigue is to get rest. Medications, stimulants, naps, exercise and other techniques are available to help in getting more sleep or staying awake when necessary. A brief discussion of current fatigue countermeasures follows.

### 1. Medications

There are many prescription and over-the-counter medications available that act as either sleep aids or stimulants. Some of these include melatonin, Sonata, Modafinil, temazepam, Dexedrine, Zolpidem, caffeine, and nicotine. This overview will highlight the effects of several commonly used sleep countermeasures.

#### *a. Caffeine and Nicotine*

Caffeine is a well-known and easily obtainable stimulant that can provide and individual with additional alertness for a few minutes up to several hours. Caffeine in amounts of 100 to 600 mg. can help maintain alertness and performance levels, particularly during long work hours or sleep deprived situations such as those commonly found in the military. Slightly higher doses of caffeine, 200 to 600 mg., were found to improve physical endurance. Since caffeine use does not pose any serious long term affects, it is recommended for military personnel on sustained operations (Vanderveen, 2001). Caffeine stimulates the central nervous system, is usually effective within 15 to 45 minutes after ingestion and lasts up to 10 hours (LeClair, 2001). Caffeine is an excellent way to extract a few more alert hours. Drinking a strong cup of coffee or soda every three to four hours will help maintain an adequate amount of caffeine in your body. Too much caffeine can lead to stomach upset and headaches. Stimulants (coffee, chocolate, soft drinks, tea) should be avoided about five to eight hours before bed. Although some people feel that caffeine does not impair their sleep, that sleep will be less restful after ingesting caffeine. Nicotine is similar to caffeine in its ability to alter your nocturnal sleep and influence your daytime sleepiness and performance (LeClair, 2001).

### *b. Melatonin*

Melatonin is secreted by the pineal gland, located between the two hemispheres of the brain, and receives its release signals from the Suprachiasmatic Nucleus (SCN) in the hypothalamus during times of darkness. Light suppresses the release of melatonin. Melatonin tablets are available in drug stores and can help speed up the re-synchronization of the body clock after crossing many times zones (LeClair, 2001).

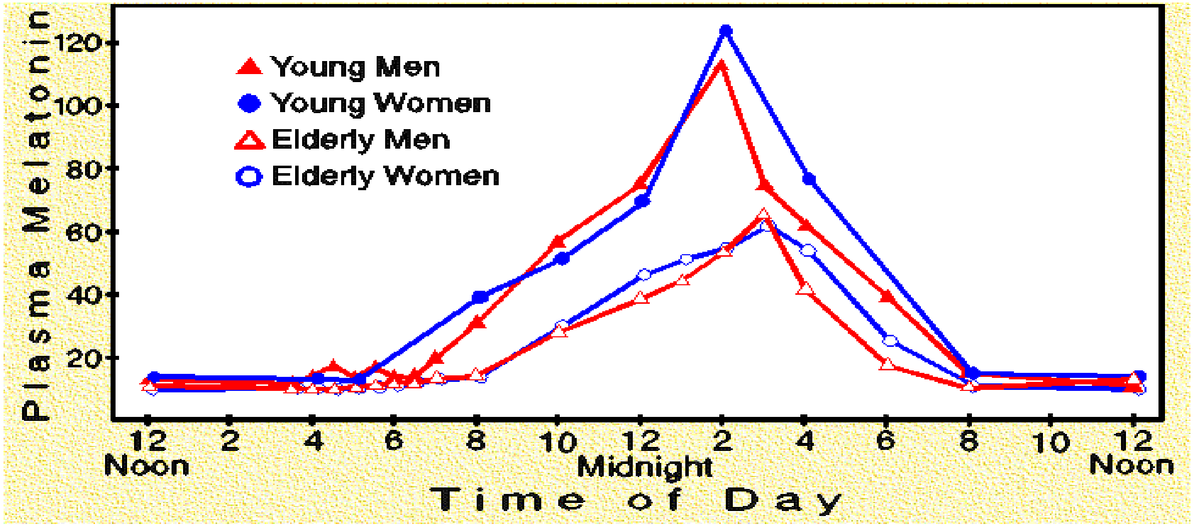


Figure 4. Melatonin Release (From: Dean, 2000)

Melatonin follows a circadian rhythm similar to other bodily functions. The release of melatonin starts in the early evening, coinciding with sunset, and for adults reaches its peak around two in the morning. As the sunrise approaches, the release of melatonin subsides, and people begin to wake up. The amount of melatonin release varies from person to person and changes throughout our lifetime. As people age, the body produces less melatonin. This explains why the elderly often suffer from sleep disorders such as insomnia and daytime drowsiness, and also why we often catch our grandparents napping (Dean, et al., 2000). Melatonin has other possible effects. Melatonin has been shown to improve mental performance, increase lifespan, help in reducing stress, help in diminish depression, and even inhibit tumor growth in a United Kingdom study of 14 cancer patients (Dean, et al., 2000).

#### *c. Modafinil and other Prescription Drugs*

Modafinil is a stimulant that can increase your attentiveness and allow you to stay awake and alert for long periods of time. One study has shown that Modafinil can prevent the reduction in attention and can reduce the amounts of errors made in a visual search for objects where speed and accuracy are important (Stivalet, et al., 1998). This same study showed when subjects took 600 mg of Modafinil every 24 hours, their high-level of vigilance was maintained up to the 44 hour mark. Other studies have produced similar results, stating that performance improved in such tasks as memory searches and response times. However, it also states that Modafinil did not keep subjects awake if there was an opportunity to sleep. It will not necessarily keep you awake but it will increase your performance when long durations of sleep deprivation are unavoidable. Another benefit of Modafinil is the low incidence of side effects (Batejat and Lagarde, 1999). This could prove valuable in the military since there are many times where demanding schedules force service member so stay awake and alert for long periods at a time.

### 2. Napping

The benefits of napping have been thoroughly studied and documented. The beneficial effects depend on three factors: the duration of the nap, the duration of the prior sleep episode, and position of the nap relative to the circadian rhythm (Batejat and Lagarde, 1999). Depending on the situation, a short or long nap may be beneficial. If there is only a limited time available, a power nap of less than 30 minutes can help restore cognitive effectiveness. The nap should be less than 30 minutes in order to avoid going into stage three or four sleep. Once in this stage, drowsiness or grogginess is usually felt upon awakening. If a longer time period is available, a 90 minute or three hour nap is valuable. The average time to complete a full sleep cycle is thought to be 90 minutes and waking up after this interval is not difficult. Two complete cycles may be completed without disrupting any regular nighttime sleep patterns, however, more than three hours can decrease nighttime sleep quality and quantity. If allowed, it has been demonstrated that napping can be beneficial at work during authorized times and places (LeClair, 2001).

The amount of sleep received the previous night is important in determining a nap time and duration. In a military study conducted by Belenky and others of the Walter Reed Army Institute of Research, subjects were deprived of sleep for 48, 72 and 85 hours of sleep. The subjects were tasked with several cognitive performance tests throughout the sleep deprivation period and were graded on speed and accuracy. In the 48 and 72 hour groups, subject's performance decreased linearly with additional hours of sleep deprivation. In the 85 hour group, subjects were allowed a 30 minute nap every day. These subjects' performance degraded linearly like the 48 and 72 hour groups, but at a slower rate. The 30 minute nap decreased the rate of performance degradation, even when the subjects were deprived of sleep for 13 more hours (Belenky, et al., 1996).

Strategically positioning a nap according to your circadian rhythm is important as well. One study showed that a two hour nap from noon to two p.m. after 53 hours of sleep deprivation was more valuable than a two hour nap from 4 a.m. to 6 a.m. after only 45 hours of sleep deprivation (Batejat and Lagarde, 1999). If drowsiness is a problem during the afternoon dip in alertness, taking a nap is beneficial. If work conditions allow it, either a short power nap or a longer nap will restore cognitive performance.

### 3. Good Sleep Habits

In addition to everything above, the following guidelines for effective sleep are offered as a general 'rule of thumb' regarding good sleep habits. Establish regular routines for sleep. Going to bed at different times sends conflicting signals to your body and alters your circadian rhythms back and forth. Avoid alcohol, particularly a few hours before bedtime. Even though it is commonly used as a sedative prior to going to sleep, it disrupts the REM sleep during the first half of the night and causes rebound and withdrawal effects in the second half. Do not eat close to bedtime. Digestion slows during sleep and may cause gastrointestinal disorders. Going to bed hungry is not good either. Eating a snack prior to going to bed to relieve the hunger pains is acceptable

(LeClair, 2001). Exercise can help maintain the circadian rhythm as well as keeping your body in good physical shape. A brief period of exercise to stimulate your heart and raise your blood pressure can alleviate drowsiness and help you become alert and attentive again. Moving around will keep your blood pressure and heart rate from falling too low. Brief 5-10 minute exercise intervals can combat fatigue. Stretching or isometrics can help too. Washing your face or brushing your teeth has an invigorating effect. Eating right helps the body maintain a proper rhythm too. Complex carbohydrates (pastas, cereals, breads, rice) and foods rich in tryptophan (fowl, legumes) can promote sleep. For example, warm milk or chicken soup. Foods low in carbohydrates or high in protein help fight fatigue. Sugar can give a boost. However, sugary foods need to be consumed at about 45 minute intervals in order to avoid a “sugar crash.” Drink lots of water or juice. Healthy meals, fruits, vegetables and dairy products, like yogurt, are a must. Bring a lunch of your own to work if there is no other dining facility or it is only a ‘fast food’ restaurant that isn’t necessarily healthy. Use brighter lights to illuminate your workplace. If your environment must be dark, find a bright place and stay there for at least 30 minutes. Bright lights will suppress the release of melatonin. Make your sleep environment optimal. Set the temperature where you like it. Get the pillows and covers just right. Use cloth covered light protectors for your eyes if you are trying to sleep in a lighted environment. Similarly, use noise protectors for your ears if it is too noisy (FAST-TR, 2002).

## I. SLEEP IN THE MILITARY

Sleep in the military, particularly in the Navy, is usually not the primary concern of the scheduling officer. In those who request sleep or complain about not getting enough sleep, it is often seen as a sign of weakness. Watch standing requirements often do not even allow for proper intervals or duration of sleep. Additional training requirements and mandatory personnel qualifications standards leave very little room for personal time for oneself and less time for sleep. Ships have demanding operational schedules and often call for long underway periods and deployments that can be grueling on a sailor’s body and sleep patterns. Taking naps is not always acceptable nor is there time available to do so. Lack of sleep is sometimes seen as a badge of honor, with sailors bragging about their minimal amounts of sleep and arguing about who got the least sleep.

Officers usually show a concern for their troops and their sleep needs, yet ignore their own. With increased sleep deprivation comes the possibility of catastrophic operational failures (ship collisions), fratricide and other accidental deaths or otherwise preventable noncombatant casualties, loss of emotional control and blind obedience to militarily irrational or illegal orders (Shay, 1998).

At Boot Camp, the Recruit Division Commanders have occasionally viewed sleep as an annoyance to their training schedule. When the sleeping schedule was changed from six to seven hours of sleep per night, the Recruit Training Command staff had to revise the entire 63 day recruit training schedule. In order to provide for the additional sleep hours, 34 hours of curriculum was consolidated or revised and 50 hours of drill and administrative time was eliminated (Burke, 2002). Resistance to change was high and was also affected by factors such as civilian galley hours of operations and other civilian contracts already in place.

## J. SUMMARY

Although it is not known exactly why we need sleep, it is known what happens when we don't get enough sleep. Performance degradation, fatigue, altered mood states and daytime sleepiness are just a few examples. The necessary amount of daily sleep varies from person to person and changes throughout our lifetimes. We need the most sleep as infants and then as children and on through adolescence. As we get older, our nighttime sleep quantities decrease and our daytime naps increase due to a number of factors, one of which is the declining production of melatonin. Social cues and other zeitgebers keep our circadian rhythms in check to coincide with our 24 hour day and reset our natural 25 hour biological clock. Sleep is vital to our learning process and can greatly improve our lives in many ways, including the reduction of risk of death in situations such as sleeping while driving. There are many fatigue countermeasures available to help us get enough sleep and/or to prevent it when necessary by stimulating the central nervous system with compounds such as caffeine. The bottom line is that sleep is a necessity. It is up to each person to determine how much sleep they need and then to take appropriate measures to ensure they get it when they need it.

# III. METHODS

## A. OVERVIEW

The objective of this thesis is to study the sleep patterns of U.S. Navy recruits in Great Lakes Recruit Training Command. This research involves analysis of sleep patterns and activity levels collected by wrist activity monitors (WAMs), demographic data, and performance as measured by test scores on three separate recruit assessment tests. The data collection occurred from April to June 2002, comprising one complete cycle of recruit initial training, or Boot Camp. The actigraph data were analyzed and 'smoothed' in order to highlight the specific areas of interest, namely the nighttime sleep patterns and any daytime sleep episodes, or naps. Throughout the data collection period, the actigraphs were downloaded at weekly intervals to minimize a potential loss of data. Test scores and attrition rates were obtained from personnel stationed at Great Lakes, Naval Training Center.

## B. SLEEP DATA COLLECTION AND ANALYSIS TOOLS

Wrist activity monitors (brand name Actigraphs) were used to collect sleep and activity level data. Actigraphs were initialized and downloaded via the Act Millennium software package developed by AMI, current version of 2001. At the end of the data collection, the data were smoothed, analyzed and converted into other readable formats via the Action W-2 program, also developed by AMI. The Fatigue Avoidance Scheduling Tool, FAST, built on modeling principles of SAFTE, (the Sleep, Activity, Fatigue and Task Effectiveness Model, described below) was an additional analysis tool that specifically investigated the fatigue and predicted effectiveness levels. Recruit test scores, demographic data and any other data were collected via various databases and through local points of contact at Great Lakes, Naval Training Center.

### 1. Actigraphs

Volunteers from the recruit population wore WAMs on their wrist for the entirety of Boot Camp. An actigraph is very similar to a wristwatch in size and shape and measures one's activity. Lack of activity represents periods of sleep. The actigraph contains an accelerometer that can be set to record activity in epochs varying from one second up to one minute. In this study the actigraphs were set to collect data in one-minute epoch lengths. There are several types of commercial actigraphs available. The recruits wore two different types, the older Tri-Mode model (which incidentally experienced a very high failure rate) and the Sleep-O model, both manufactured by AMI and on loan from the Walter Reed Army Institute of Research (WRAIR). For the purposes of this thesis, only the data from the Sleep-O watches was used (comprising approximately the final two weeks of Boot Camp).

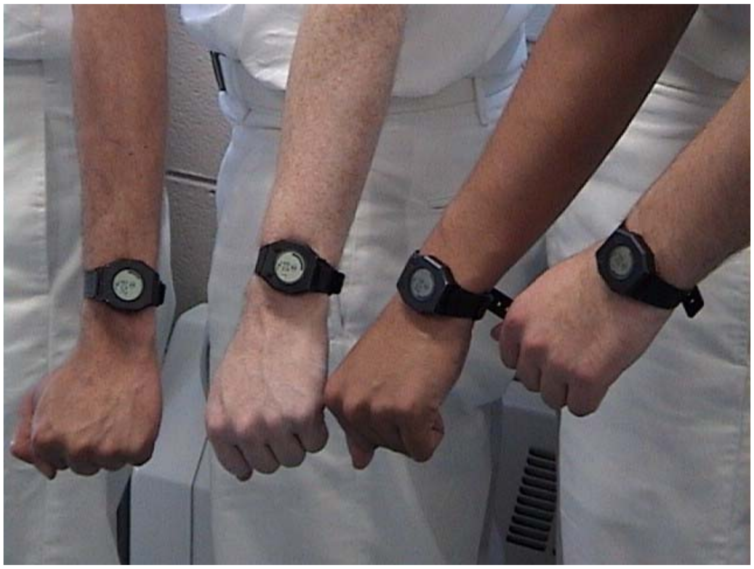


Figure 5. Recruits Wearing Actigraphs

### 2. Ambulatory Monitoring, Inc.

Act Millennium is the computer program used to initialize and download the actigraphs and data. Ambulatory Monitoring, Inc. (AMI), Ardsley, New York is responsible for producing Act Millennium. Local time, type of actigraph, sampling modes (e.g., zero crossing mode, time above threshold mode), epoch length, actigraph identification number, when to start recording data, estimated runtime, and a header preview are all reviewed and set during initialization. AMI also has a diagnostics program that allows you to check the settings of the actigraph reader and to ensure the accurate transmission of data. During Boot Camp, the recruits participating in this study had their actigraphs downloaded once per week, usually on Saturday mornings to minimize the interruption of training. Each actigraph was connected manually to the actigraph reader, data were downloaded into the computer and then saved into the participant's data file.

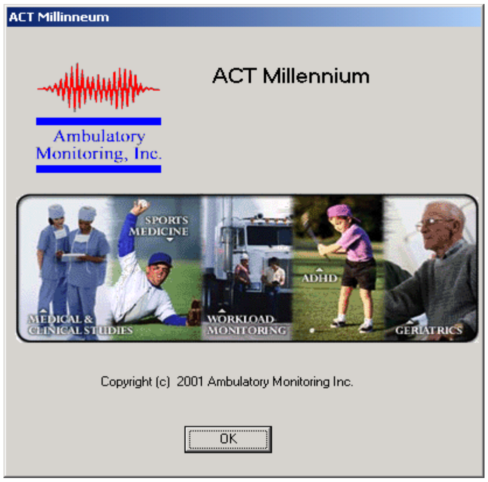

ACT Millinneum
ACT Millennium
Ambulatory Monitoring, Inc.
SPORTS MEDICINE
MEDICAL & CLINICAL STUDIES
WORKLOAD MONITORING
ADHD
GERIATRICS
Copyright (c) 2001 Ambulatory Monitoring Inc.
OK

Figure 6. Act Millenium Startup Screen

### 3. Initial Processing of the WAM Data: AW2

Ambulatory Monitoring, Inc also produces Action W, Version 2 (AW2). AW2 allows visualization of the activity levels for the entire data collection period. It scores

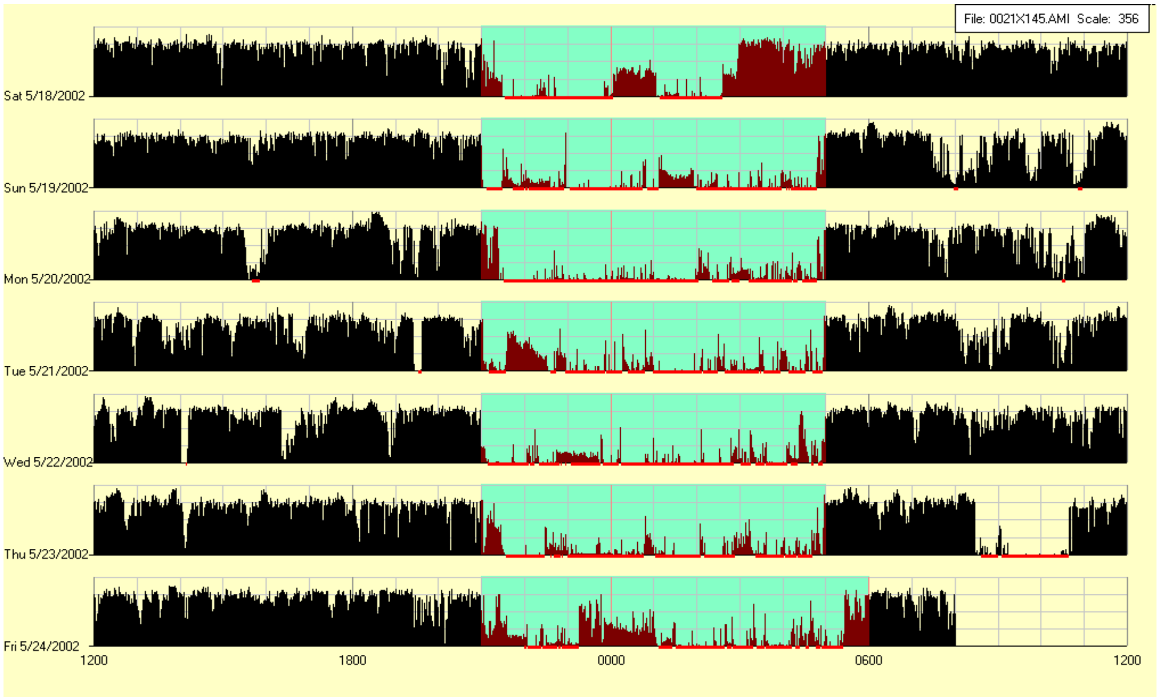


Figure 7. Action W-2 Linear Actigraph View

the sleep and wake periods and offers manual ‘fine-tuning’ of the data if the user deems it necessary. Basic statistics can be run using AW2 such as total sleep minutes, wake minutes and percentages of time spent sleeping. The Cole-Kripke algorithm is used when scoring the sleep and wake periods. This method, developed in 1988 and revised in 1992, uses a weighted average of the previous four minutes, the current minute and the next two minutes in order to determine whether the current minute should be labeled as ‘sleep’ or ‘wake.’ Additional ‘re-scoring’ rules are enforced after the sleep and wake periods have been scored to allow for the correction of the more obvious discrepancies that may result from using the weighted average. More information on Action W and the sleep scoring algorithms can be found in the program’s online Help Menu or the AW2 manual.

### 4. The Sleep, Activity, and Fatigue, Task Effectiveness Model (SAFTE)

The Sleep, Activity, and Fatigue, Task Effectiveness model shows how the time of day (circadian rhythms) and sleep/wake patterns influence cognitive capacity and error. The model takes into consideration the progressive increases in sleep deprivation (fatigue), the effects of the time of day (circadian rhythms) on performance, and the changes in time of work and sleep (shift work and transmeridian phase shifts). The model also takes into account the quality of sleep and sleep inertia, which is the temporary slowing of performance immediately after awakening. Its purpose is to generate predictions of performance to anticipate fatigue and guide changes to improve safety and effectiveness. The figure below shows the SAFTE model along with the sleep reservoir and other inputs into determining sleep effectiveness.

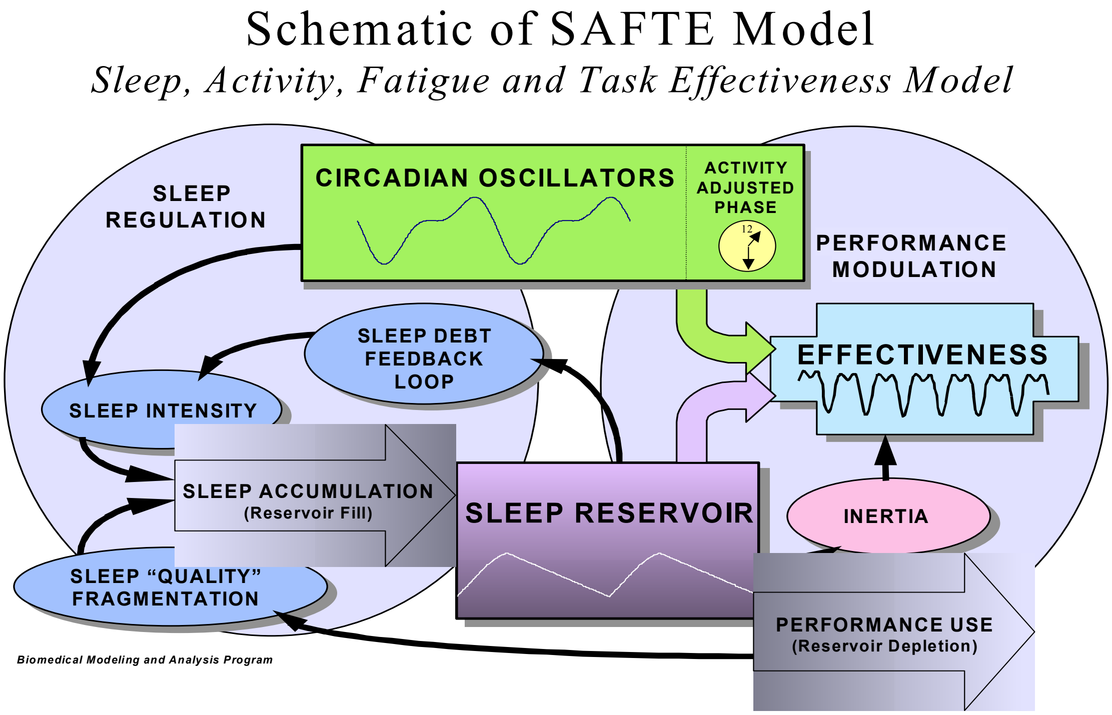

Schematic of SAFTE Model
Sleep, Activity, Fatigue and Task Effectiveness Model
SLEEP REGULATION
CIRCADIAN OSCILLATORS
ACTIVITY ADJUSTED PHASE
12
PERFORMANCE MODULATION
SLEEP DEBT FEEDBACK LOOP
EFFECTIVENESS
SLEEP INTENSITY
SLEEP ACCUMULATION
(Reservoir Fill)
SLEEP RESERVOIR
INERTIA
SLEEP "QUALITY" FRAGMENTATION
PERFORMANCE USE
(Reservoir Depletion)
Biomedical Modeling and Analysis Program

Figure 8. Sleep, Activity, Fatigue, and Task Effectiveness Model

The main component of SAFTE is a sleep reservoir, shown in the center of the schematic of the model. A fully rested person is considered to have a ‘full tank’ or a full sleep reservoir, as represented by the reservoir capacity. While awake, the sleep reservoir is gradually depleted and while asleep, the sleep reservoir is replenished. The rate of accumulation, sleep intensity, is driven by our circadian rhythms and its changes, and the current sleep deficit, which is calculated from the sleep reservoir level and is shown by the sleep debt feedback loop circle in the schematic. This sleep deficit is constantly changing. As a person sleeps, the reservoir is replenished; while awake, the reservoir is depleted. Sleep accumulation is also affected by one’s sleep quality, or how soundly one sleeps without interruptions throughout the night. The fluctuations in the reservoir level are reflected in the sleep-wake cycle and anything less than a ‘full tank’ represents a current reservoir deficit. Finally, sleep accumulation does not start immediately upon retiring to sleep. There is a brief delay of about five minutes required to achieve a restful sleep state. The level of the reservoir expressed as a percentage of its capacity is a major factor determining percent cognitive effectiveness. The circadian rhythm based on the time of day is also a major input into determining cognitive effectiveness. (FAST help menu, SAFTE model architecture)

### 5. Fatigue Avoidance Scheduling Tool

The Fatigue Avoidance Scheduling Tool (FAST) is a computer program that allows data to be imported which were downloaded and edited in other programs. FAST gives estimates of an individual's predicted effectiveness based on the SAFTE model described in the previous section. It uses an algorithm created by Dr. Steve Hursh in conjunction with the Walter Reed Army Institute of Research (WRAIR) called SAFTE, the Sleep, Activity, and Fatigue, Task Effectiveness model, and graphically shows sleep efficiency in daily blocks with detail to the minute. It assumes the subject has had two nights of full rest (eight hours of sleep); hence the subject enters the first day of data collection with a full sleep reservoir. FAST then analyzes each minute of data and graphically represents one's sleep efficiency. Sleep intervals and work periods are depicted on the horizontal axis. The vertical axis represents the effectiveness, and the right hand side shows either the acrophase in hours or a blood alcohol equivalent measure. The main display is shown in colors that represent degrees of effectiveness. The highest section is green indicating excellent effectiveness, followed by yellow indicating reduced effectiveness. The bottom portion is red and indicates periods of unacceptable effectiveness. This zone is set at less than 65% effectiveness. A dotted line at 78% is also shown and at this level it is believed that one's effectiveness is at an unacceptable or ineffective level (based on U.S. Air Force standards). Additional tools allow the user to analyze the data in many different ways, such as minute-by-minute effectiveness or by altering start times and durations of wake periods. A subject's actigraph data can be input into FAST, and their effectiveness levels can be predicted and graphically displayed. For this study, FAST has been used to show the predicted effectiveness of the recruits while at Boot Camp.

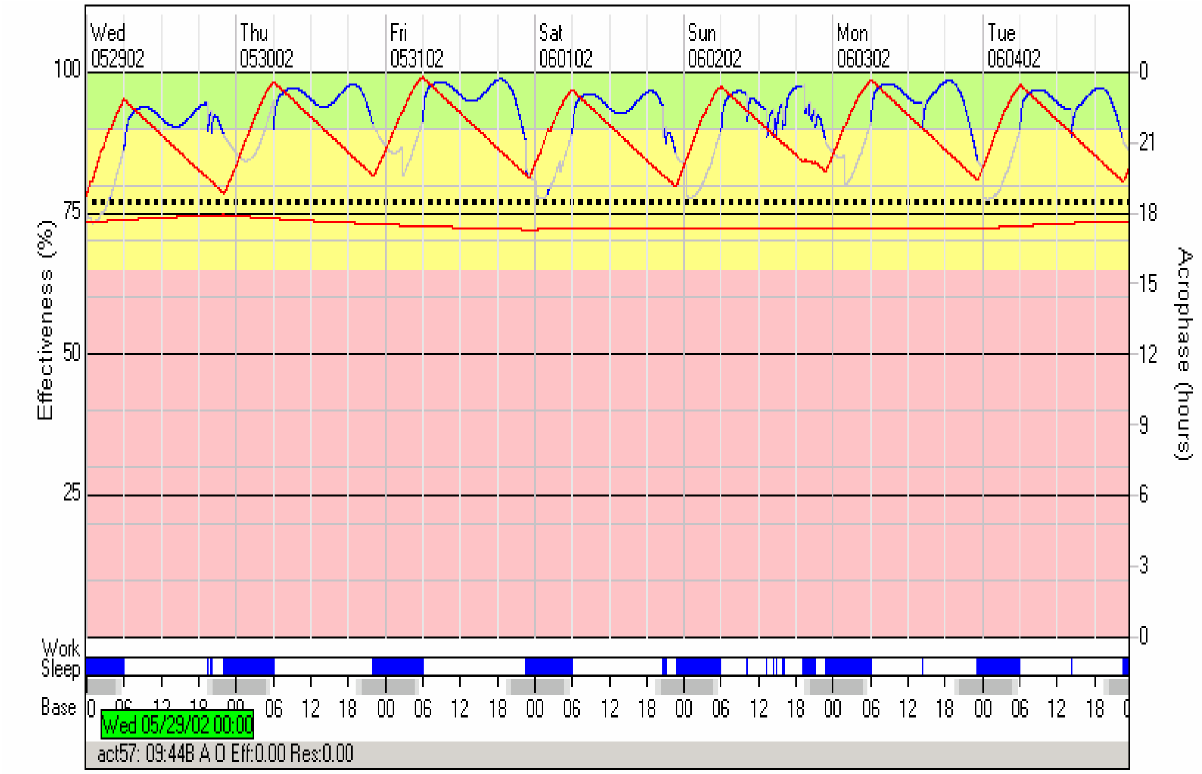


Figure 9. FAST Evaluation Screen

## C. SUBJECTS

Subjects for this study were new recruits entering basic training, or Boot Camp, in April, 2002. Volunteers were briefed about the study being conducted and then asked to sign participant consent forms, privacy act forms and a minimal risk form (see Appendix B, C, and D). The participants were asked if they had any questions and after signing the forms, they were instrumented with an actigraph. The instructions for wearing the actigraph were given to them and points of contact were provided if they had any concerns or questions later. Their respective Recruit Division Commanders were also informed of the study. Prior permission and approval for the study was obtained from senior officers at the Great Lakes Naval Training Center, including Rear Admiral Rondeau, the Commanding Officer. Initially there were 35 volunteers wearing the older Tri-Mode actigraphs. Due to high actigraph failure rates, on May 18, 2002 these older actigraphs were replaced with the newer Sleep-O model. Thirty-one participants had useable data, 20 males and 11 females, from five different recruit divisions (division numbers 224, 219, 218, 217 and 216). The sample was stratified by gender because a question of interest to the leadership at RTC was whether sleep patterns differed by gender. Actigraphs were collected upon graduation, resulting in two to three weeks of useable data for most participants.

## D. SUMMARY

There are many tools available to use when analyzing sleep. A few simple ones have been addressed above. Additional methods include fully equipped sleep laboratories with EKG, EEG, EMG and other monitoring devices. These laboratories may offer overnight sleep monitoring to analyze sleep patterns and to diagnose sleep disturbances or abnormalities. The non-intrusive methods and equipment described above offer an opportunity to conduct simple quantitative analyses. By wearing an actigraph for a specified period of time, one can estimate sleep and wake periods, sleep efficiency, number of sleep and wake episodes and their duration, and many other sleep factors. By analyzing the data as described here and in the next chapter, decisions can be made about effectiveness of sleep regimes and behaviors, and how to improve them.

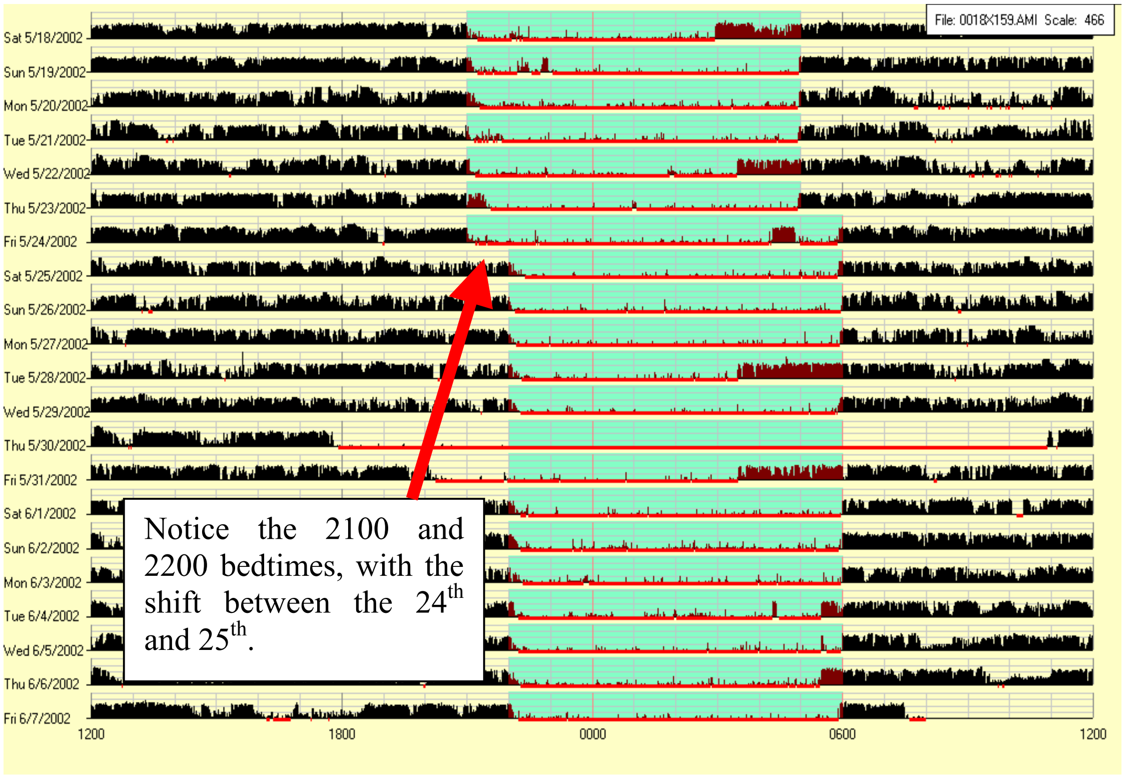
# IV. ANALYSIS

## A. OVERVIEW

This study analyzed data collected using 31 actigraphs from U.S. Navy recruits in Boot Camp. This chapter is divided into two sections: 1) data conditioning and sample selection; and 2) descriptive statistics and comparisons by group. The data from the 31 recruits was copied from the AW2 program and analyzed with Microsoft Excel and SPSS for Windows. Most comparisons refer to the average amount of sleep per night for that category. Only in specific instances are the averages per person compared. We note that the number of nights of data vary among recruits from 2 to 21 nights.

## B. DATA CONDITIONING AND SAMPLE SELECTION

The data were compiled and saved in one location. Since the actigraphs were downloaded weekly, there were many copies of actigraphy data. As expected, some



Notice the 2100 and 2200 bedtimes, with the shift between the 24th and 25th.

Figure 10. Action W-2 Linear Actigraph View

actigraphs failed at various times throughout the study and the weekly downloads proved beneficial for the security of the data. When multiple files existed for one actigraph, the file with the most data (the longest duration of time while wearing the watch and collecting data) was used for analysis. The data from the actigraphs were then processed with AW2. The self-scoring algorithm shows the sleep periods and wake periods. AW2 has a scoring algorithm for the down periods; however it was not used in this case. Recruits at the U.S. Navy Recruit Training Command at Great Lakes, Illinois have strict guidelines for bedtime (TAPS) and wakeup (Reveille). Since we know that the U.S. Navy recruits are on a strict sleeping regimen, this analysis will focus primarily on the sleep that recruits receive within their designated sleep period, i.e., 2100 to 0500 and as after 24May02, from 2200 to 0600. With the actigraphs adjusted to strict 'Down' intervals, the basic statistics were run in AW2 to get the total number of sleep and wake minutes for the specified eight-hour sleep interval. Statistical analyses were performed twice, with the first time using the defined 'Down' interval only. The wake periods outside of the eight-hour sleep interval were examined in order to eliminate any daytime sleep episodes, or catnaps. These changes were made to ensure that only the sleep epochs in the specified eight-hour sleep interval were counted as sleep for that particular 24-hour day. Next, each set of data was analyzed again. The same statistical calculations were performed, but this time, for the entire 24-hours. With these two analyses, one can look at the daytime sleep episodes and compare the 24-hour sleep totals to the strict 'Down' interval sleep totals.

### C. DESCRIPTIVE STATISTICS AND COMPARISONS BY GROUP

A comprehensive examination of the data focused on comparisons of sleep amounts between groups. Males and females were compared to each other as well as comparisons for the different bedtimes (2100 and 2200), the days of the week, whether or not the recruit had a substantial sleep disruption during the night, and finally comparisons between divisions. Unless otherwise indicated, all comparisons were made using the strictly defined eight-hour nighttime interval and excluding any sleep disrupted nights. Disrupted sleep is defined as any night having at least a 30 minute period of wakefulness after sleep onset or more than 45 minutes of wakefulness from bedtime until sleep onset.

This disruption may be caused by standing a watch, a personal activity (e.g., bathroom visit), or some other activity.

### 1. Individual Participants

Figure 11 shows the distribution of each recruit's sleep levels for the duration of the study.

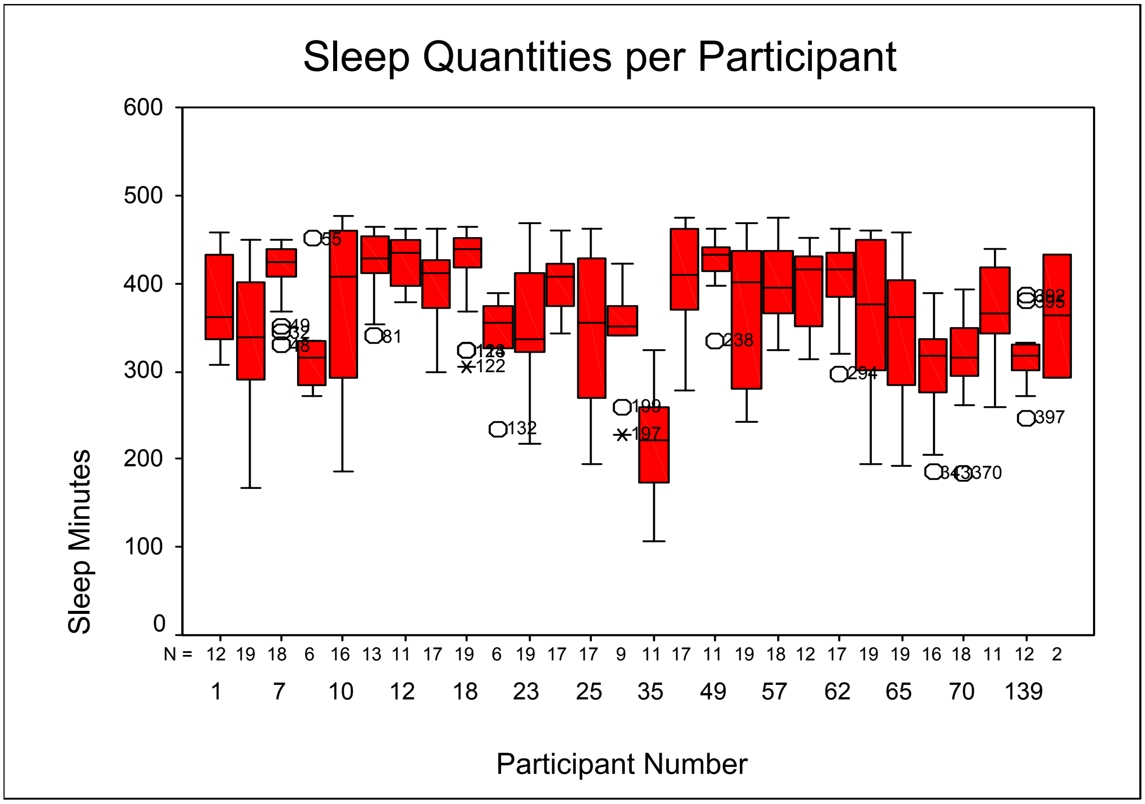


Figure 11. Box Plots of the Amount of Sleep in Minutes by Participant

The overall average amount of sleep for all recruits in this study is 368.5 minutes, or 6.1 hours of sleep per night with a standard deviation of 74.2 minutes. The shaded portion of the boxes represents the middle 50%, the line represents the median and the whiskers that extend from the box represent the highest and lowest values.

### 2. Males vs. Females

On average, females get more sleep than males: 374.1 minutes, or 6.2 hours for females and 364.5 minutes, or 6.1 hours for males. Although females received 10 minutes more sleep on average, a two-sample t-test to see if the expected average sleep differed by gender yielded a p-value of .20 indicating that there is no statistically significant difference in average sleep by gender. Similar results were obtained when examining the data to see if variability in the amount of sleep differed by gender. Again two-sample t-tests comparing the ranges of amount of sleep and standard deviations of amount of sleep for males and females yielded respective p-values of .31 and .28. These tests did not provide evidence of differences in variability in amount of sleep by gender.

Figure 12 depicts average sleep per night for males and females with nights for which sleep was disrupted separated from nights for which sleep was not disrupted. Females with no sleep disruptions received 434.4 minutes of sleep, or 7.2 hours while males with no sleep disruptions received 424.3, or 7.1 hours. For disrupted nights, females received 331.0 minutes of sleep, or 5.5 hours while males received 312.8 minutes, or 5.2 hours. Two-sample t-tests of differences in expected average sleep for males and females applied separately for nights with disrupted sleep and nights without disrupted sleep again showed no significant difference with p-values greater than .20.

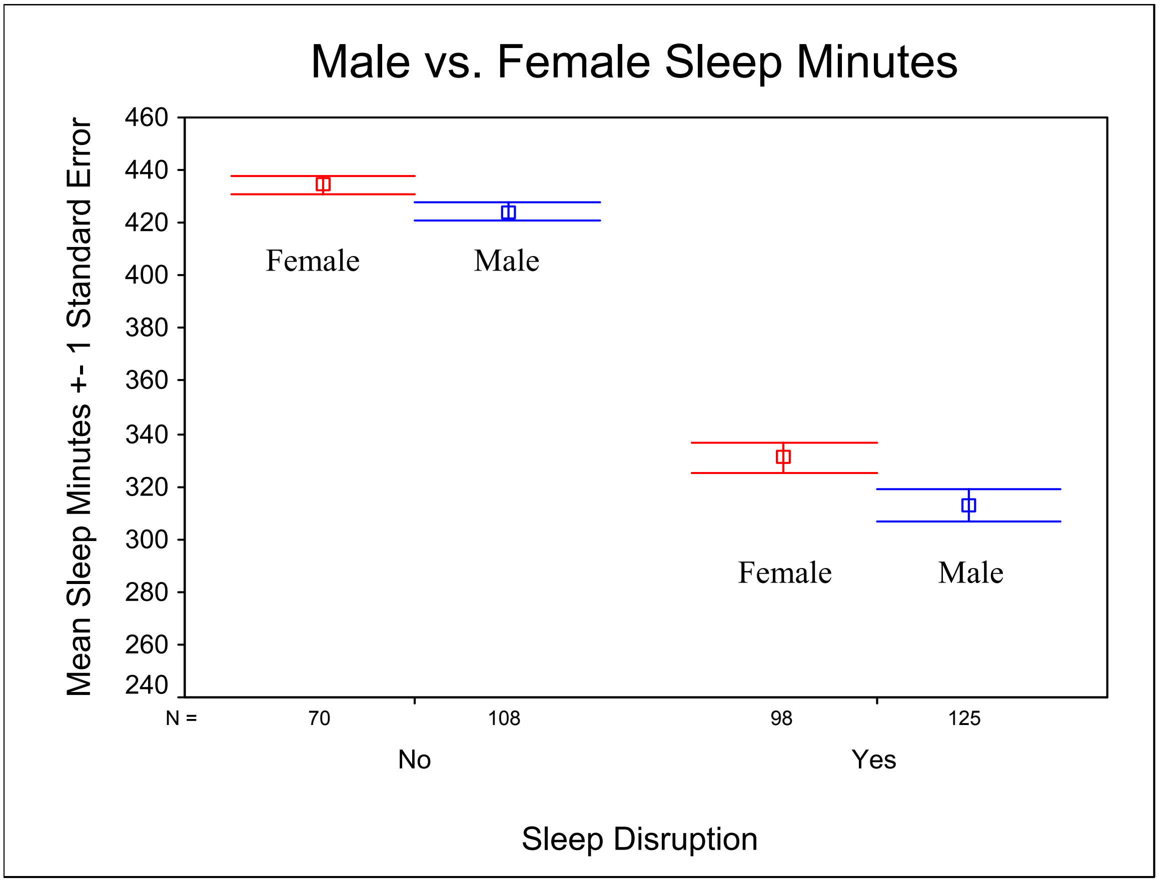


Figure 12. Average Sleep Minutes and Standard Error Bars by Gender and Disrupted/Non-Disrupted Nights

### 2. 2100 vs. 2200 Bedtime

Figure 13 compares average sleep between 2100 and 2200 bedtimes for each participant. In most cases, the 2200 bedtime offered more sleep to the recruit. A paired t-test was conducted which compared average amount of sleep for the 2100 and 2200 bedtimes. This test used all available data, i.e. it included both disrupted and non-disrupted nights. For the 2100 bedtimes, the average was 356.4 minutes, or 5.9 hours and for the 2200 bedtime, the average was 378.7, or 6.3 hours of sleep. The p-value for this t-test was .01, indicating a highly significant difference between sleep regimens. Although this is a significant finding, it is possible that the disrupted sleep nights affect the outcome of these t-tests since there were unequal numbers of disruptions for each individual in the two bedtimes.

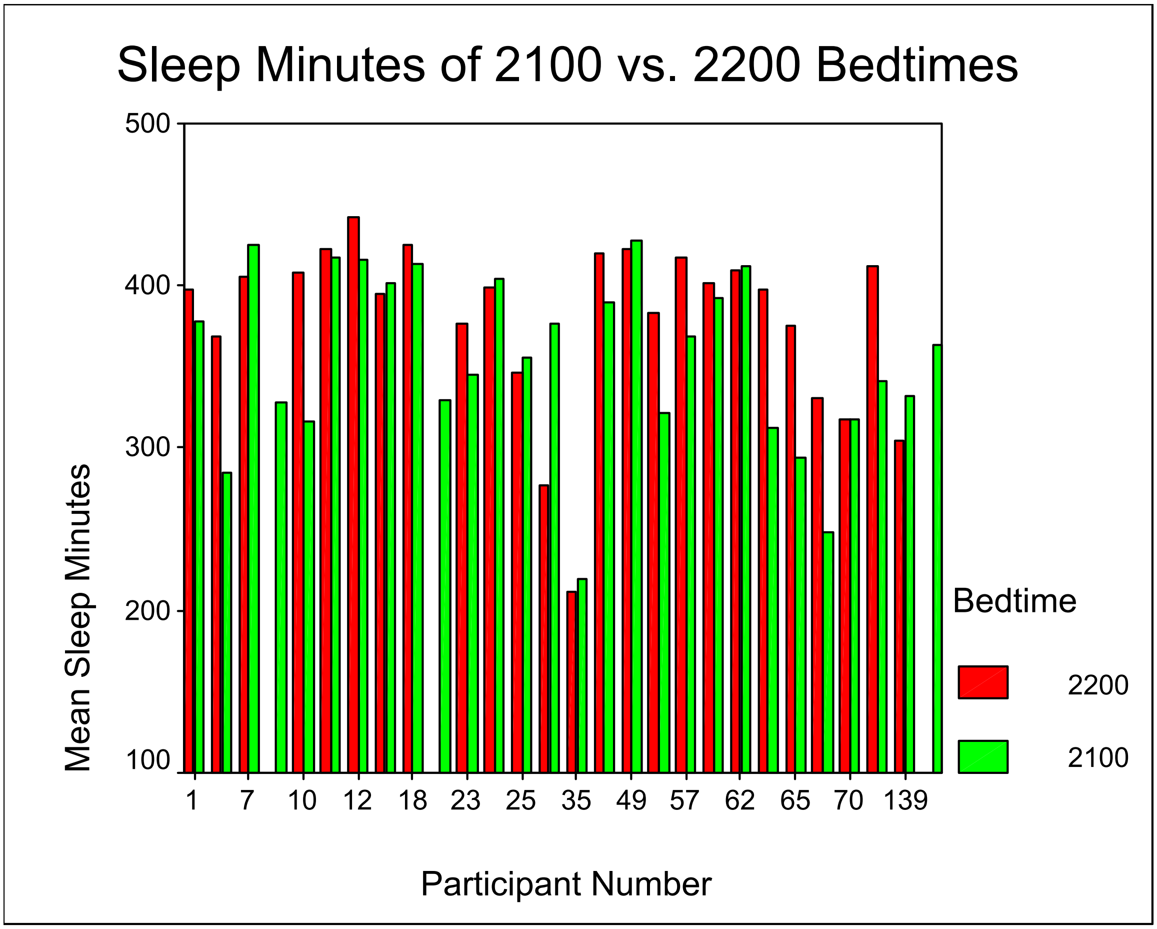


Figure 13. Average Sleep Minutes by Bedtimes and Participants

The box plots in Figure 14 highlight the difference by participant between non-disrupted and disrupted sleep nights for both the 2100 and 2200 bedtimes. Not surprisingly, Figure 14 shows that individuals get less sleep almost uniformly on nights that are disrupted. It also gives an idea about the variability of individual sleep patterns for both disrupted and no-disrupted nights. Overall, on average, recruits that have a disrupted night of sleep get 320.8 minutes of sleep, or 5.8 hours, vs. non-disrupted nights when they get 428.3 minutes, or 7.1 hours.

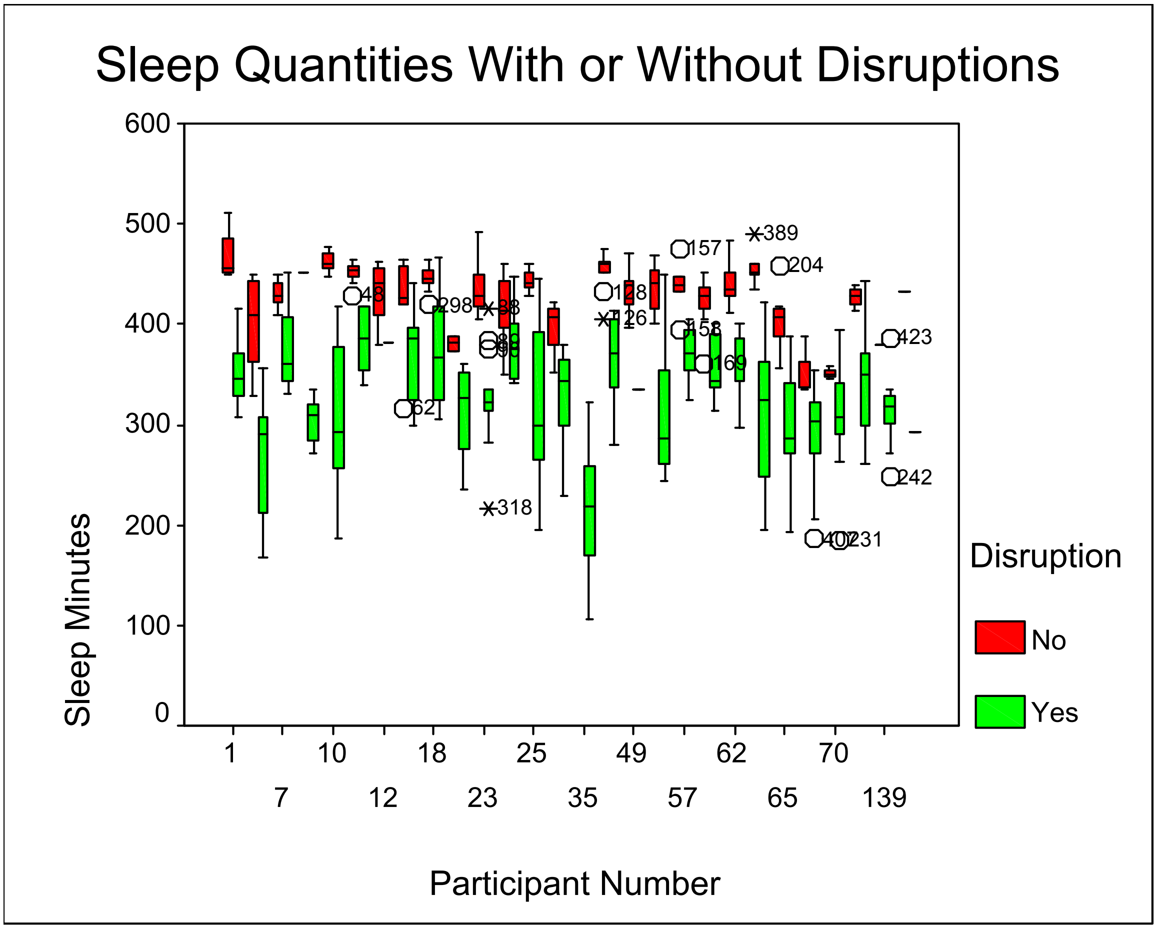


Figure 14. Sleep Quantities With or Without Disruptions

Figure 15 depicts the average amount of sleep by bedtime and by whether sleep is disrupted or not. For the 2100 bedtimes, with sleep disruption, recruits received 313.1 minutes, or 5.2 hours of sleep. With no disruptions, recruits received 425.0 minutes, or 7.1 hours of sleep. For the 2200 bedtimes, with disruptions, recruits received 328.9 minutes, or 5.5 hours of sleep. With no disruptions and a 2200 bedtime, recruits received

429.6 minutes, or 7.2 hours of sleep. It is clear that when they were disrupted, they received less sleep. Without disruptions they received 428.3 minutes of sleep, or 7.1 hours, and with disruptions they received 320.1 minutes, or 5.3 hours of sleep.

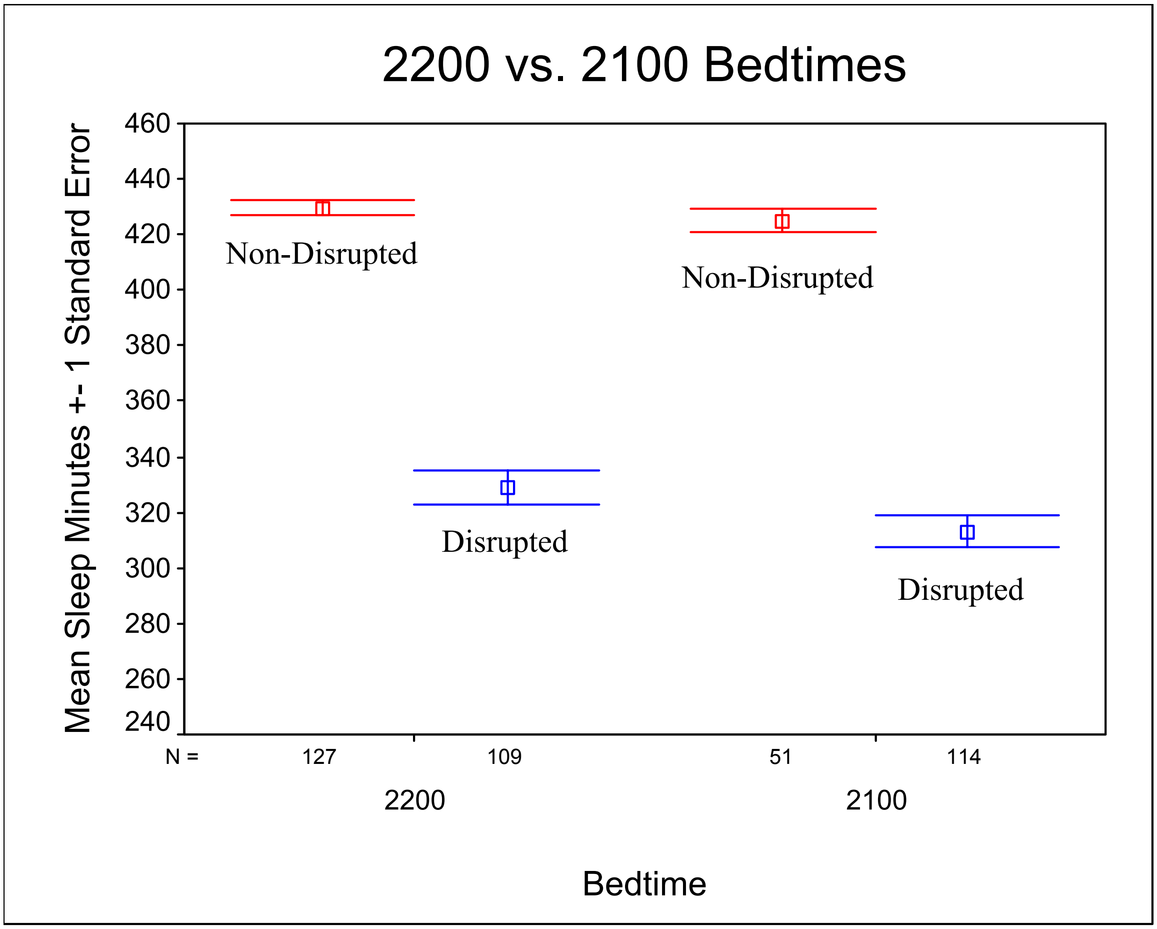


Figure 15. Average Sleep Minutes and Standard Error Bars by Bedtime and Disrupted/Non-Disrupted Nights

From Figure 15, it is apparent that there is a decrease in average amount of sleep between 2200 and 2100 bedtimes for non-disrupted night as well as for disrupted nights. Further, this decrease in average sleep is about the same for both types of nights: disrupted and non-disrupted.

Figure 16, an alternate depiction of Figure 13, underscores the difference in sleep of 2200 and 2100 bedtimes. The average amount of sleep was calculated per person for each of the two bedtimes. A scatterplot was made to show their comparison. The marks above the line indicate that a recruit received more sleep with a 2200 bedtime and the marks below favor the 2100 bedtime. Figure 16 shows that the majority of recruits received more sleep when following the 2200 to 0600 sleep regimen than when following the 2100 to 0500 sleep regimen. On average, the 2200 bedtime resulted in 22 more minutes of sleep per night per recruit. This coincides with the predictable shift in young adult circadian rhythms which favor later bedtimes.

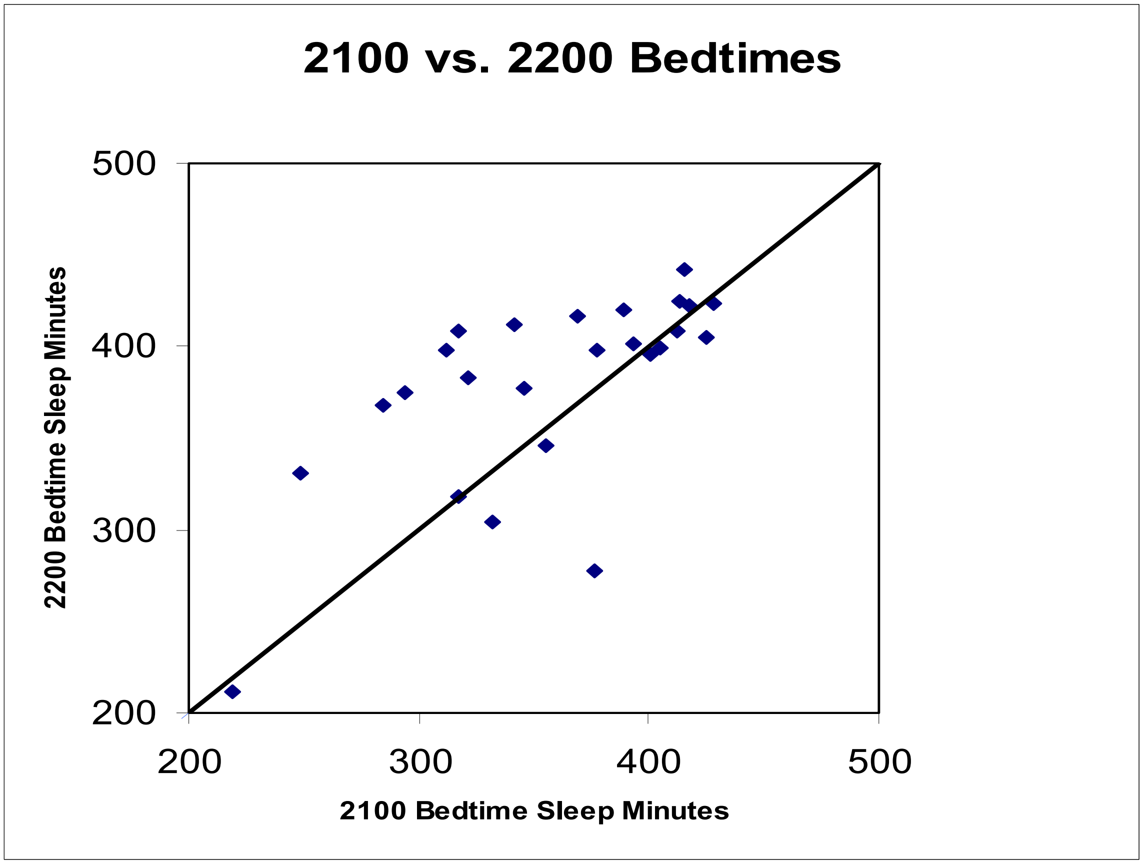


Figure 16. Average Sleep Minutes per Recruit for 2200 and 2100 Bedtimes

Figure 17 plots the difference of the average number of minutes with a 2100 bedtime and the average number of sleep minutes with the 2200 regimen. Here, participant number 27 is unusual. This recruit receives much more sleep on average in the 2100 bedtime regimen. This recruit is also unusual in that he had two out of three nights of data with substantial wake periods. If this individual were taken out of the data set or had a more regular sleep pattern for those nights, the results would further support the 2200 bedtime for recruits. For example, if one of the two unusually disrupted nights was changed to a non-disrupted night of sleep, the average number of sleep minutes that the 2200 bedtime would offer recruits would increase to 24.3 per recruit per night.

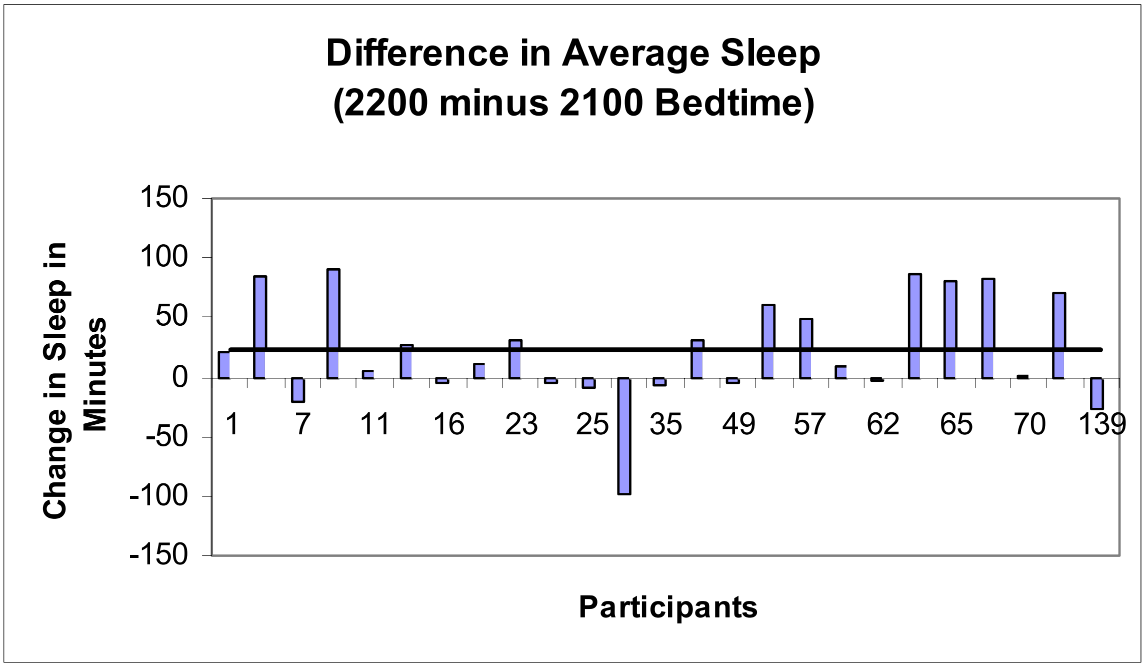


Figure 17. Differences in Average Participant's Sleep

### 3. Days of the Week

Figure 18 shows the trend in average sleep over days of the week. On average, recruits get the most sleep on Fridays (391.0 minutes or 6.5 hours) and the least sleep on Saturdays (352.9 minutes or 5.9 hours).

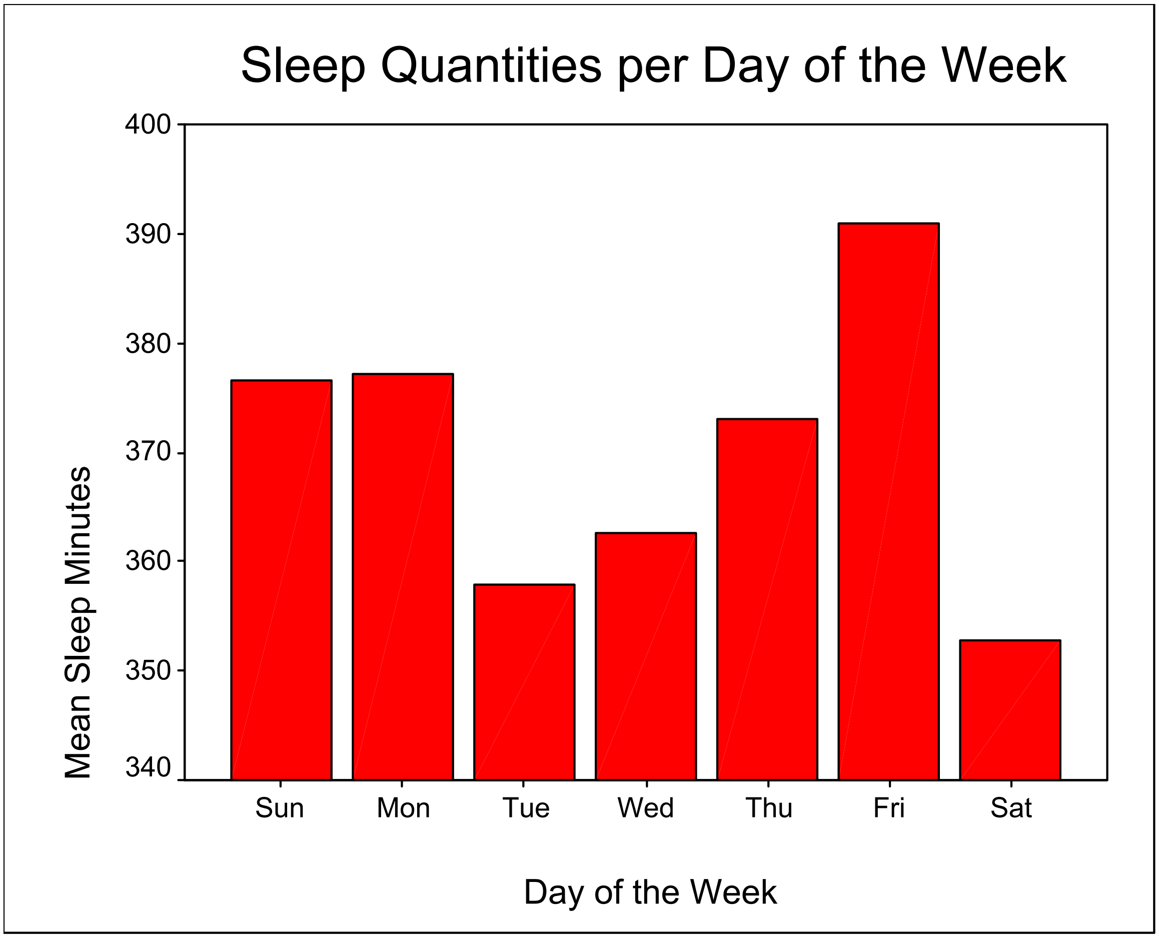


Figure 18. Average Sleep Minutes per Day of the Week

### 4. Division

The comparisons between divisions yield interesting results. As evident in Figure 19, division 219 gets the most sleep, with 404.2 minutes (or 6.7 hours) and division 224 gets the least sleep with 346.7 minutes (or 5.8 hours).

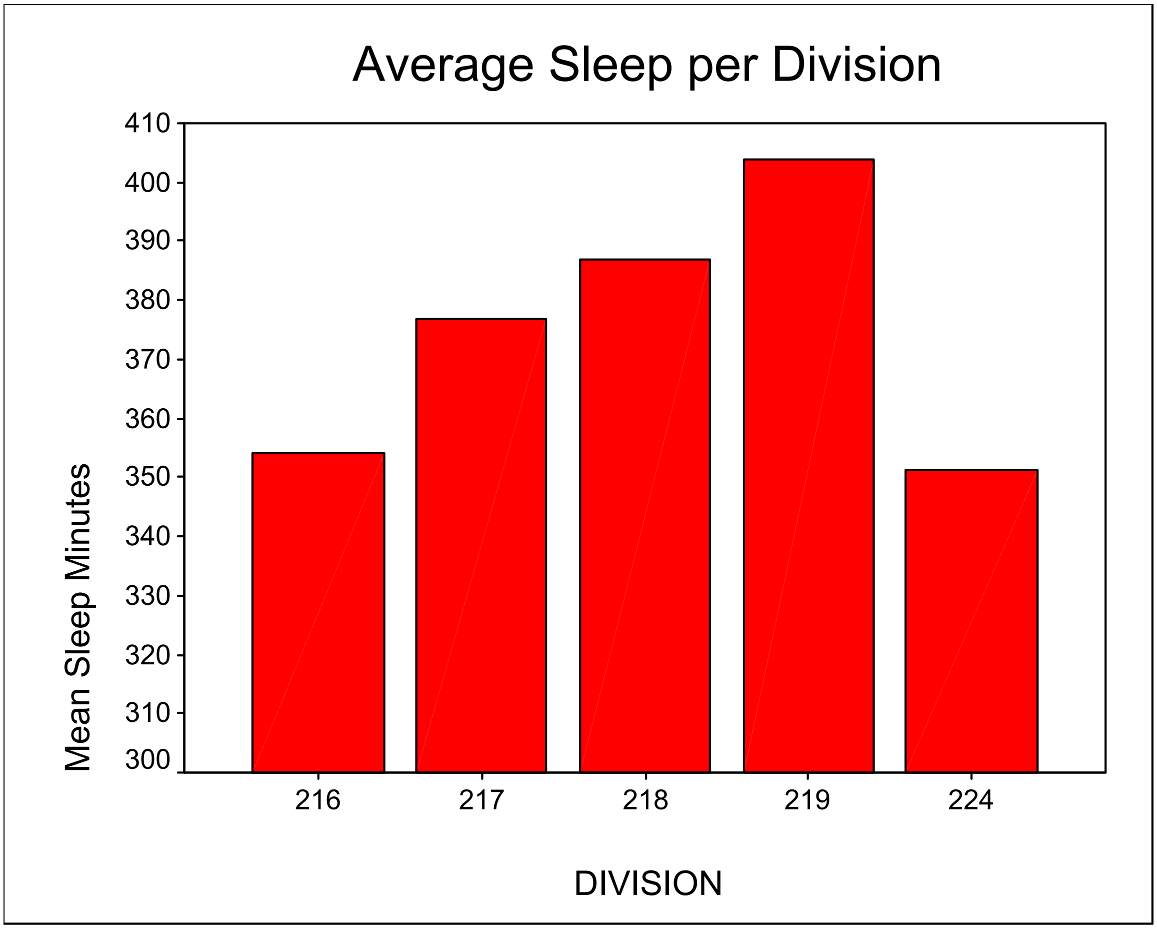


Figure 19. Average Sleep per Division

## D. ADDITIONAL COMPARISONS

The major focus of this study is the comparison between 2100 and 2200 bedtimes although other factors are also of interest, e.g., differences in sleep by gender, by sleep disruptions, by divisions, and by days of the week. In the following section, the interaction of these three factors with bedtimes and gender are considered.

### 1. 2100 vs. 2200 Bedtimes

The bedtimes were compared for differences with each division. Figure 20 shows the amounts of sleep per division for the different bedtimes. The important difference to note is in division 224. When recruits in division 224 went to bed at 2100 they received 298.0 minutes of sleep compared to 375.5 minutes when they went to bed at 2200.

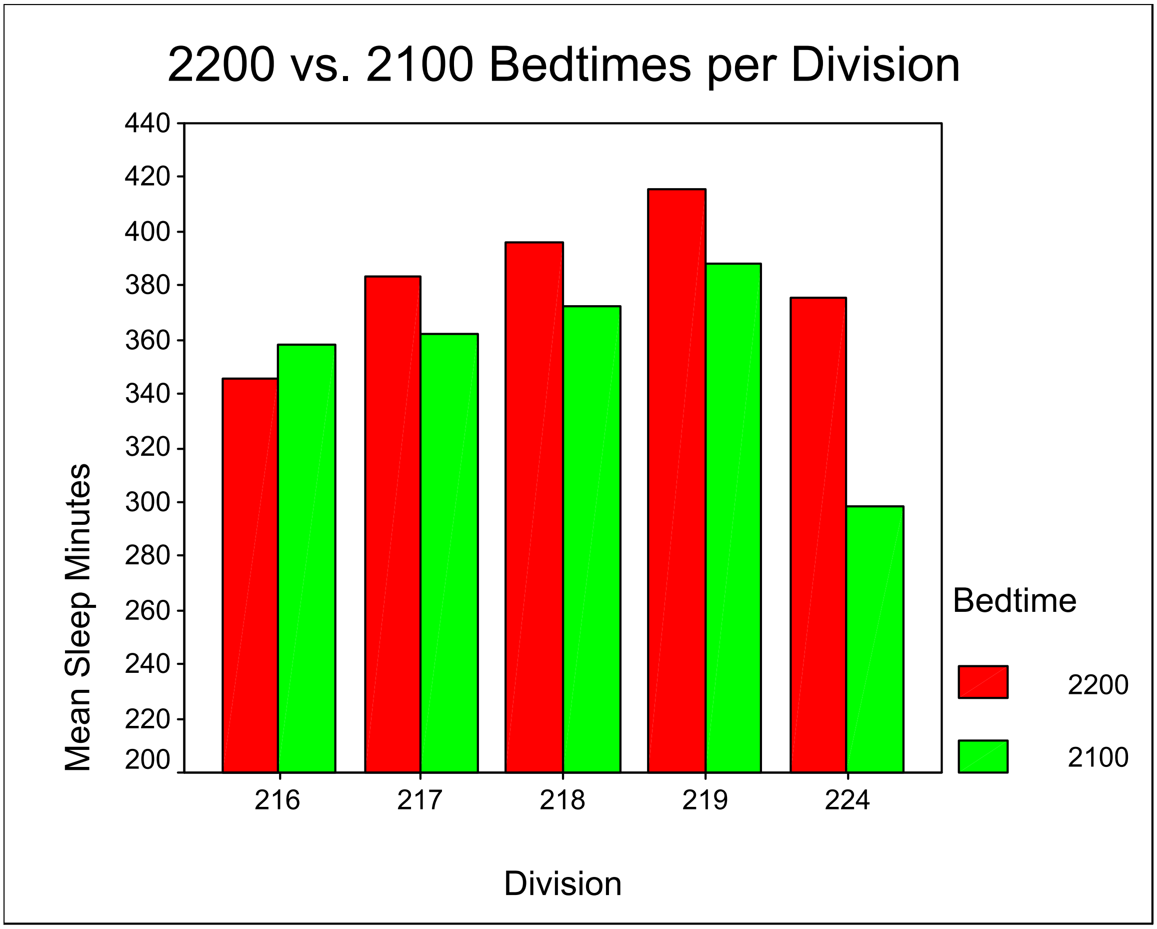


Figure 20. Bedtimes per Division

The different bedtimes were compared to the days of the week. As expected, with the exception of Friday, the 2200 bedtimes gave recruits more sleep. On Fridays, the 2100 bedtimes gave recruits an average of 27 more minutes of sleep compared to the 2200 bedtimes. An explanation for this difference is that this result includes an interesting data point. On May 24th, the recruits switched both bedtimes and awakening times. Some divisions shifted both times at once, whereas, some maintained the 2100 bedtime and allowed the recruits to sleep until 0600, affording them a one night only nine hour sleep interval.

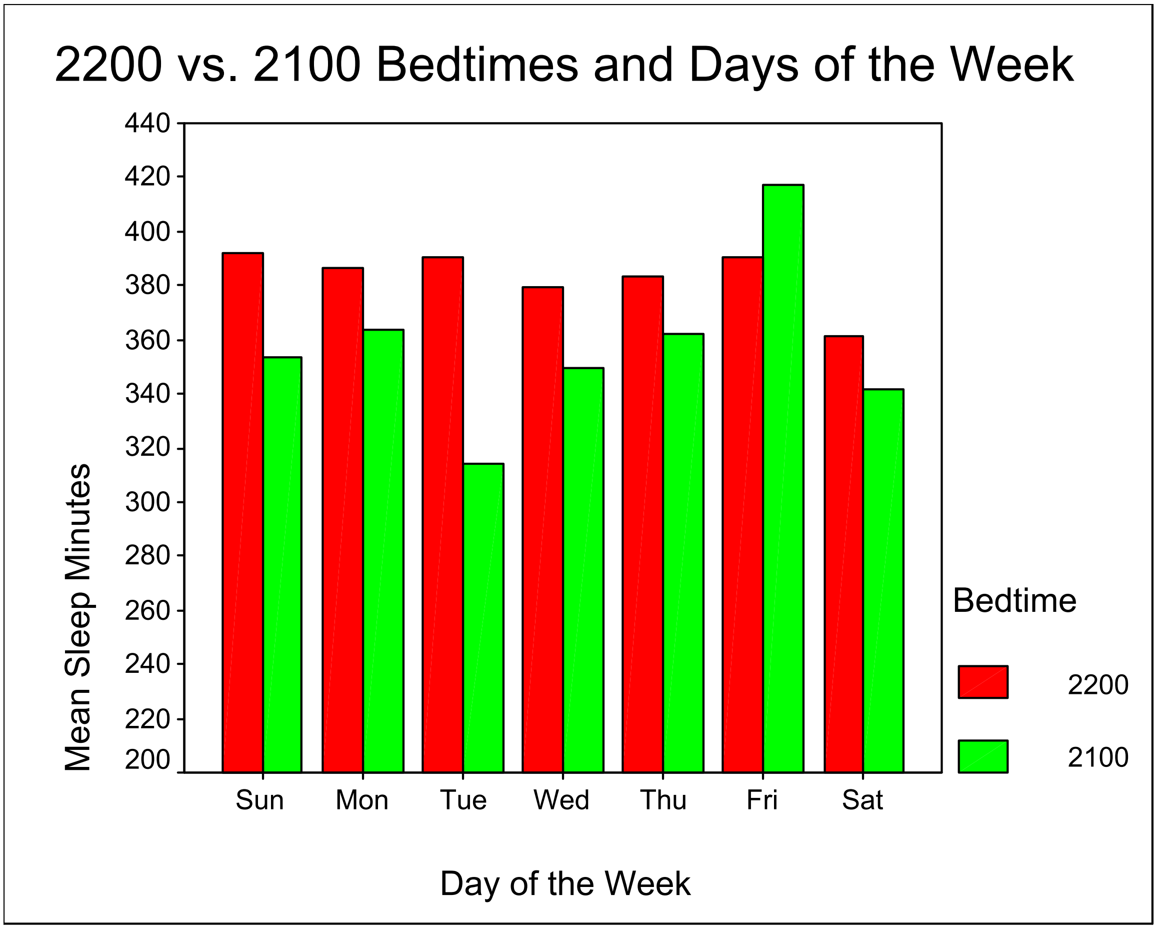


Figure 21. Bedtimes and Days of the Week

### 2. Males vs. Females

Only divisions 217, 218 and 224 were co-ed divisions or integrated with both males and females. Male only divisions 216 and 219 are included for comparative purposes. The comparisons show that on average, when all divisions are included, there is very little difference between sleep quantities of males and females (females received 1.7 minutes more sleep). However, in divisions 224 and 218, females received considerably more sleep than did their male counterparts (23.0 and 67.7 minutes respectively). Contrary to this, in division 217, males received more sleep than females by 19.1 minutes. All of these comparisons included nights with disrupted sleep. Figure 22 illustrates these results.

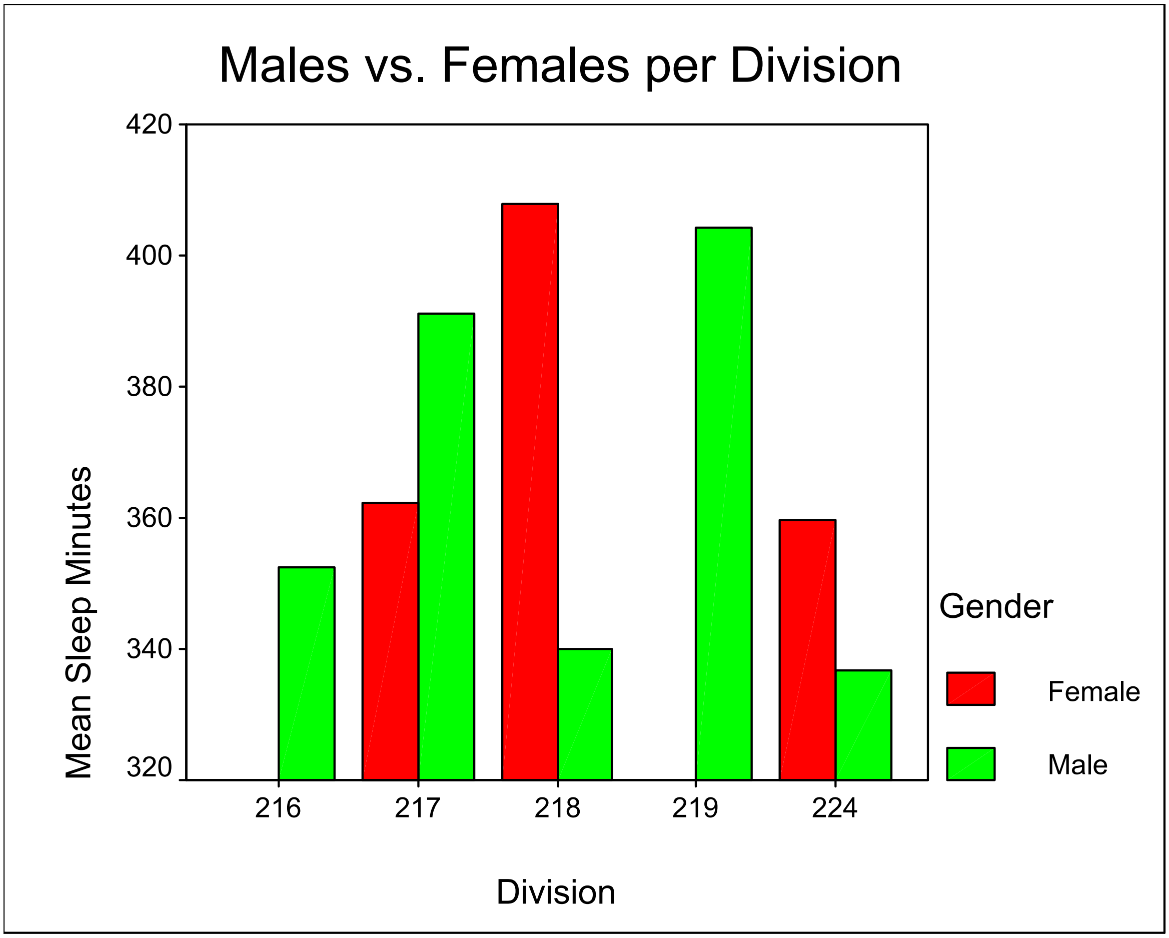


Figure 22. Gender per Division

The comparison between males and females on each day of the week (Figure 23) yielded interesting results, particularly for Friday. The difference between males and females generally agrees with overall trends. However, on Fridays, females receive 29.5 more minutes of sleep than males. Males actually receive more sleep than females on Wednesdays by 17.4 minutes.

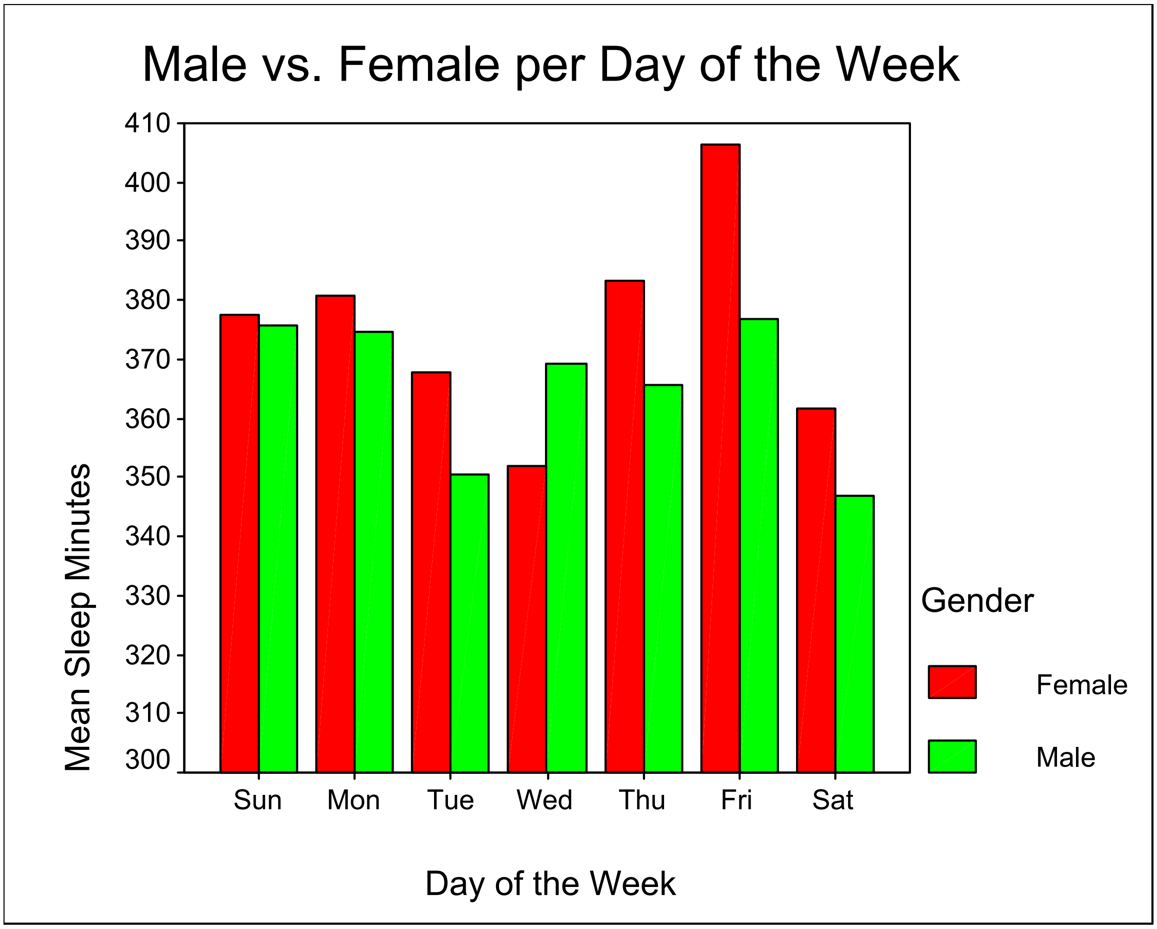


Figure 23. Gender vs. Day of the Week

The comparison between males and females (Figure 24) for the 2100 and 2200 bedtimes showed small differences in sleep amounts, with females receiving 7 more minutes with 2200 bedtimes and 11 minutes with 2100 bedtimes.

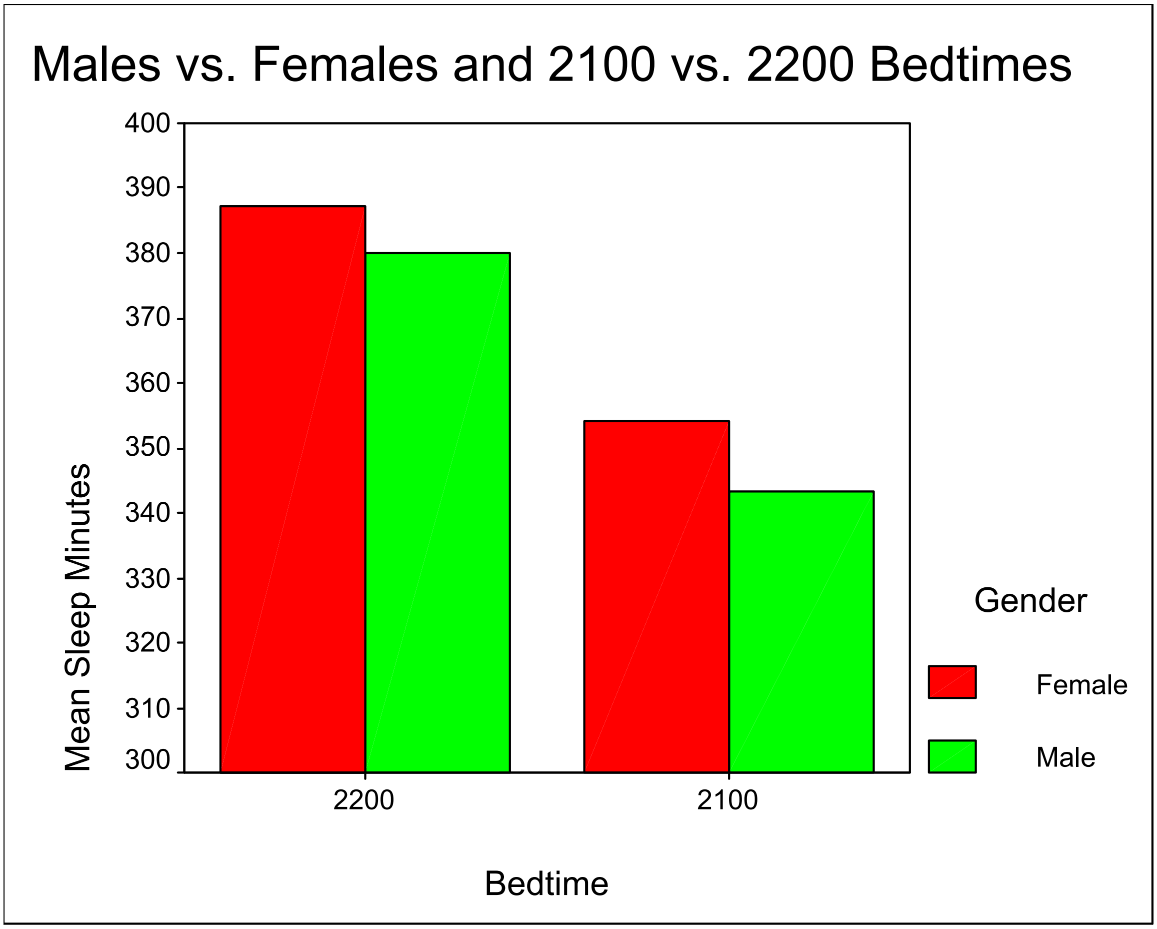


Figure 24. Gender vs. Bedtime

## E. SUMMARY

The descriptive analysis in this chapter compares relevant factors of recruit sleep regimens. Statistical differences were reported where applicable. Otherwise, simple comparisons were shown. The primary focus of these comparisons was between the 2100 and 2200 bedtimes. The data clearly show that recruits get more sleep with a 2200 to 0600 sleep regimen. Although the findings are not statistically significant, females usually got more sleep than males regardless of disruptions or not, bedtimes and for most days of the week. Only in division 217 did males get more sleep minutes per night than females.

# V. CONCLUSIONS AND RECOMMENDATIONS

## A. CONCLUSIONS

Recruits at the Great Lakes Recruit Training Center are getting less sleep than scheduled. Even though they are allotted eight hours of sleep per night, the average amount of sleep is well below that amount. With a 2200 bedtime, recruits received significantly more sleep per night than when they go to bed at 2100. Not surprisingly, nights with disrupted sleep have a tremendous effect on the average minutes of sleep received. There are differing levels of sleep per division (the greatest amount of sleep is in division 219 with 404.2 minutes and the least amount of sleep is in division 224 with 346.7 minutes) and per day of the week (the greatest amount of sleep is on Friday nights, with 391.0 minutes). In this study, female recruits received slightly more sleep on average than their male counterparts.

## B. LESSONS LEARNED

Future field studies that attempt to assess fatigue and sleep patterns should be monitored as closely as possible. Irregularities occurred during the data collection that could have been corrected or better accounted for if known prior to completion. Participants should keep an individual sleep log, annotating watch standing periods, any periods of unusual wake or sleep, times when the actigraph was not worn, i.e. not collecting data, and reasons that explain these circumstances. Requests were made to have recruits complete these logs, but were repeatedly denied. Daily schedules according to a Plan of the Day or standard routine need to be documented also. For example, obtaining an official watch standing schedule from the Recruit Division Commanders would allow for the comparison between scheduled watches and activities and the participants activity log. A generic schedule for the entirety of Boot Camp was received, however its generality and flexibility made it a vague reference tool and not a specific source of valuable information. Obtaining this data from different points of contact is useful in solving discrepancies or deciphering contradictory information.

Data analysis can never begin too soon. Conducting data analysis concurrently with the data collection is recommended. Sometimes more information or additional data is needed or wanted after the study is in progress. If the data collection is still proceeding, the study can be adjusted to collect more or different data.

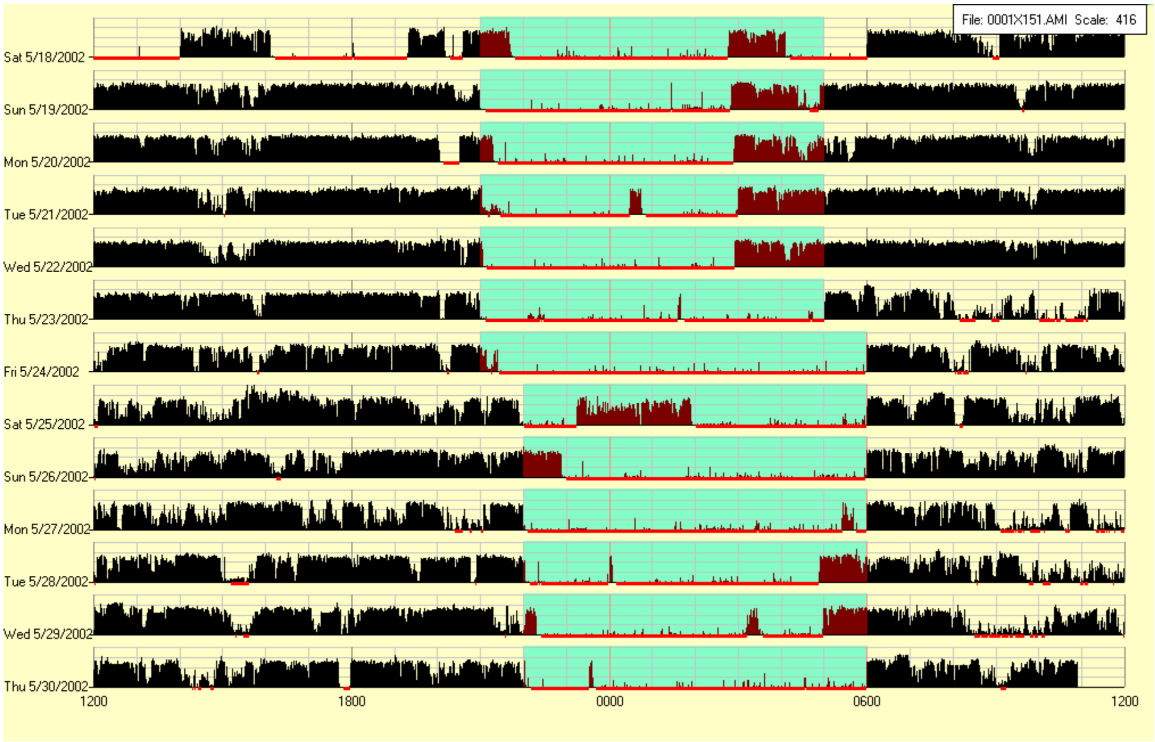
## C. FUTURE WORK AND RESEARCH OPPORTUNITIES

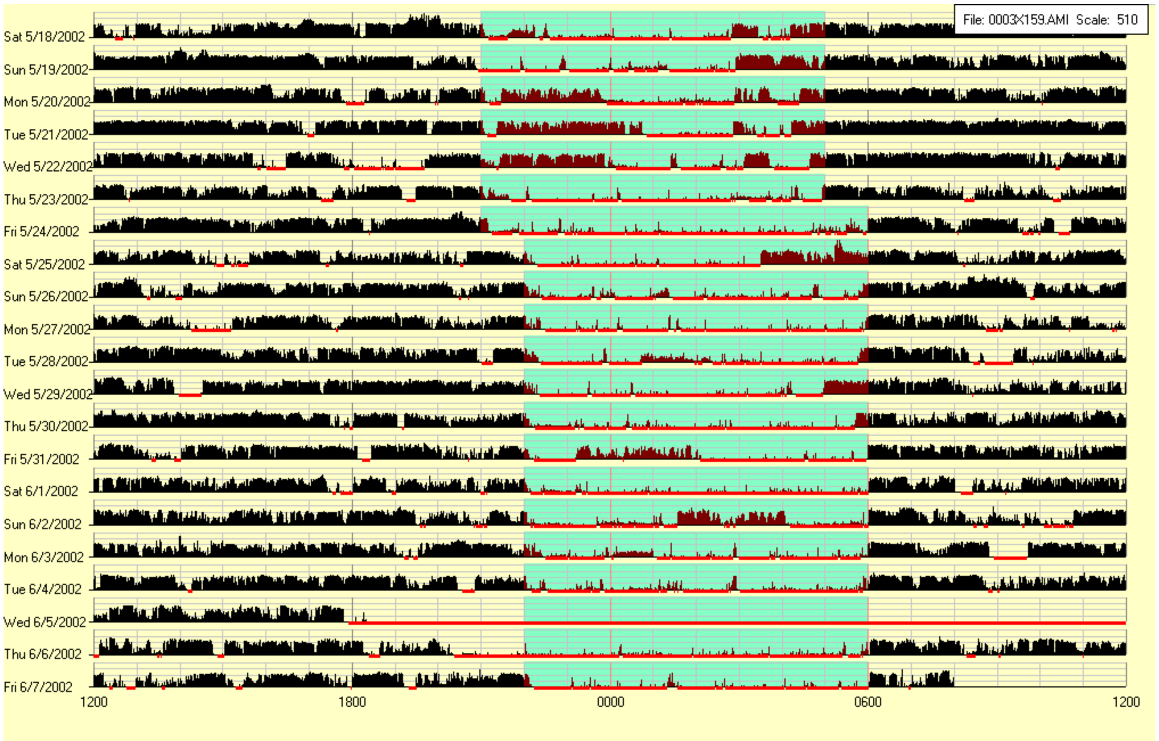
There is an abundance of information from this study about the 31 recruits studied. While the sleep minutes have been analyzed from many different viewpoints, there is still much that can be done. Action W-2 provides several statistics regarding an individual's sleep and activity. Quality of sleep and wake episodes were reviewed but not fully analyzed. Sleep latency, wake after sleep onset and other variables could all be researched further. Most of the analysis conducted in this thesis dealt with the specific 8-hour designated sleep interval set by the Recruit Training Command. Analyzing the 24-hour periods as a whole will offer different total sleep amounts when considering daytime naps and microsleeps. A thorough analysis of the recruit's predicted effectiveness according to the FAST model can also be conducted.

Recruit test scores were obtained but not analyzed. By comparing sleep levels and effectiveness predictions against performance measures such as test scores and attrition rates, a determination of the quality of training can be made as well as suggestions for improvement. With the test scores, attrition rates and other performance measures, a regression type analysis can be used to predict the performance variables when sleep amounts are known. Analyzing these results will offer an opportunity to adjust training schedules to further improve Boot Camp.

The finding indicating more sleep with a 2200 bedtime cannot be overstated. As the literature shows, young adult's circadian rhythms signal the body to go to sleep later and wake up later in the morning. Further adjustments to the sleep regimen at Great Lakes Recruit Training Center could continue to increase the average daily sleep amounts and improve the quality of recruit training, sending them to the fleet better equipped. Schedule adjustments do not have to be universal throughout the training week. Allowing for a few hours of catch-up sleep on the weekends will have a minimal impact on the overall training cycle and will help fill a recruit's sleep reservoir and potentially eliminate sleep debt or overcome sleep deprivation.

# APPENDIX A. ACTION W-2 PARTICIPANT ACTIGRAPH PRINTOUTS

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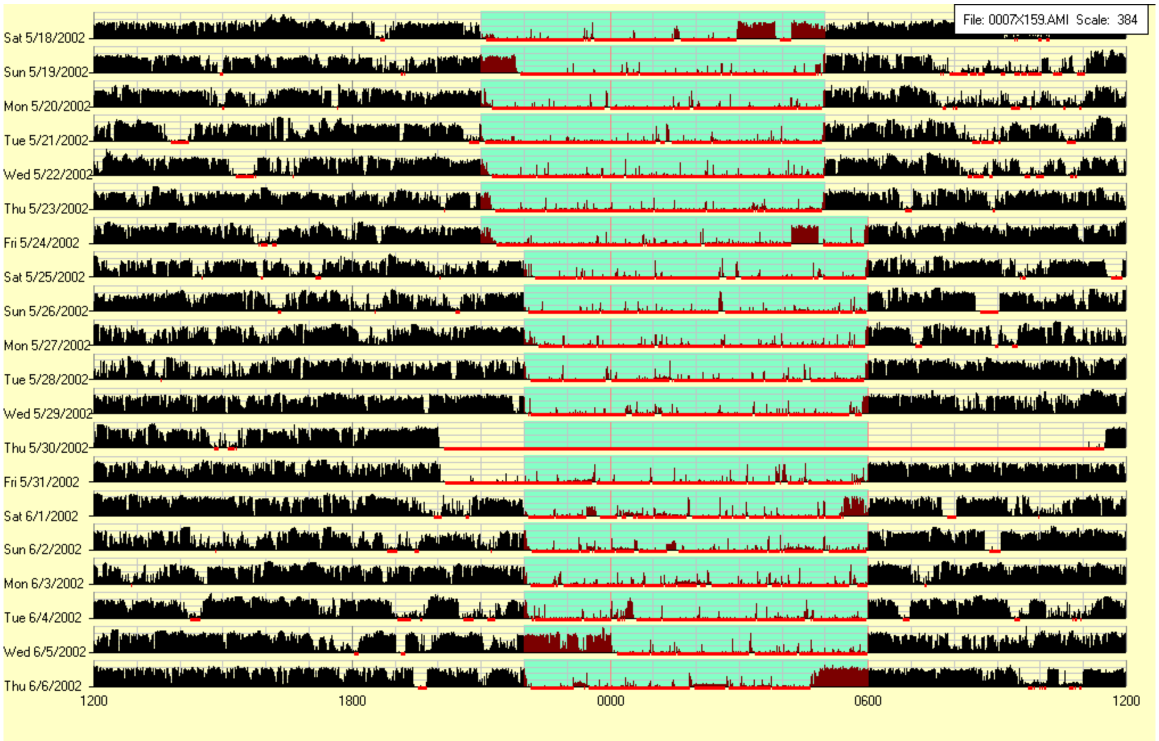
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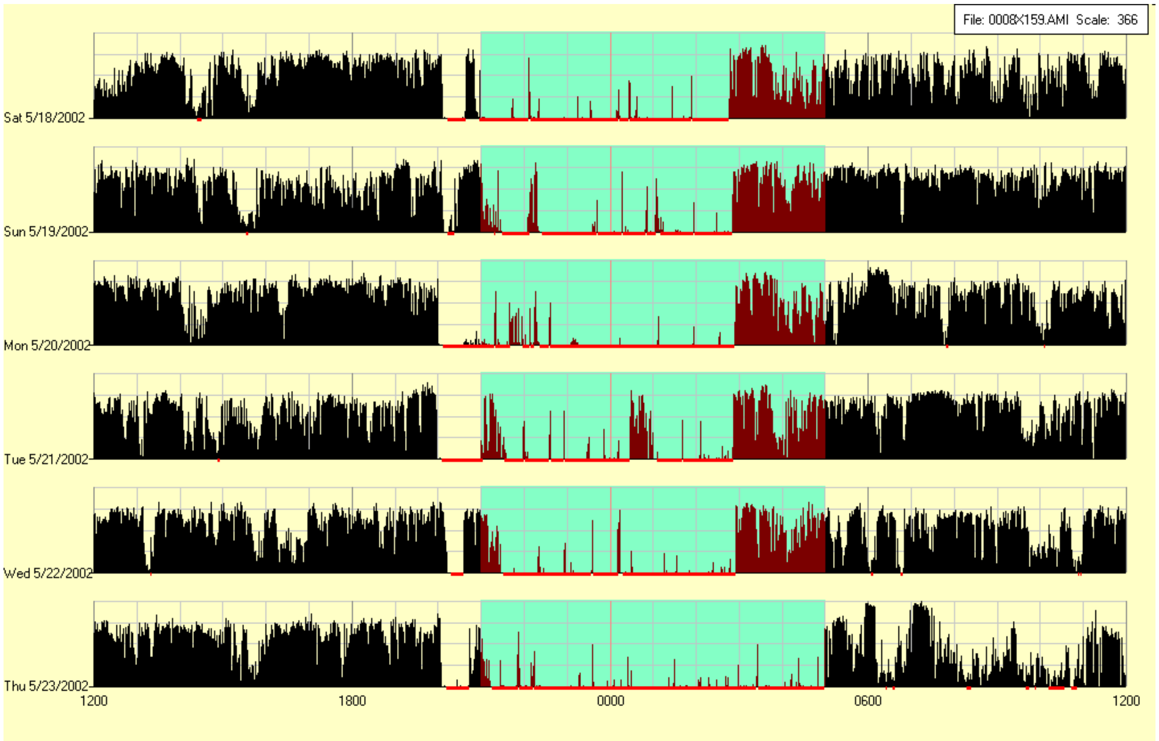
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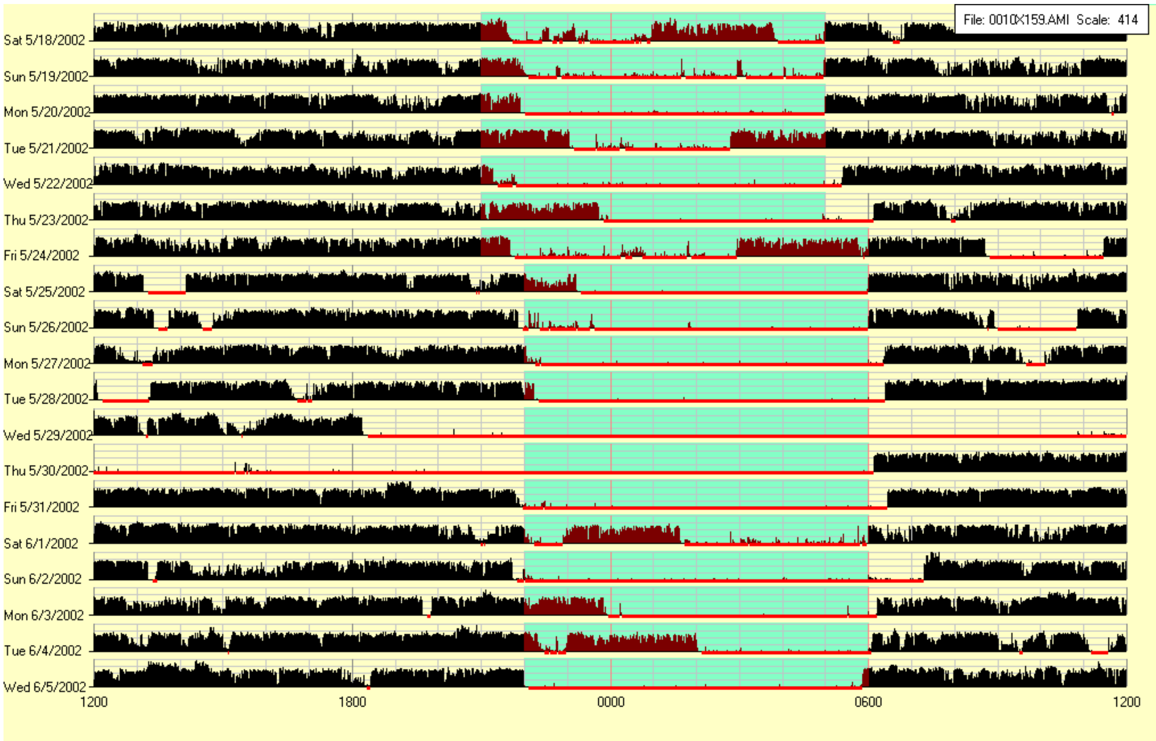
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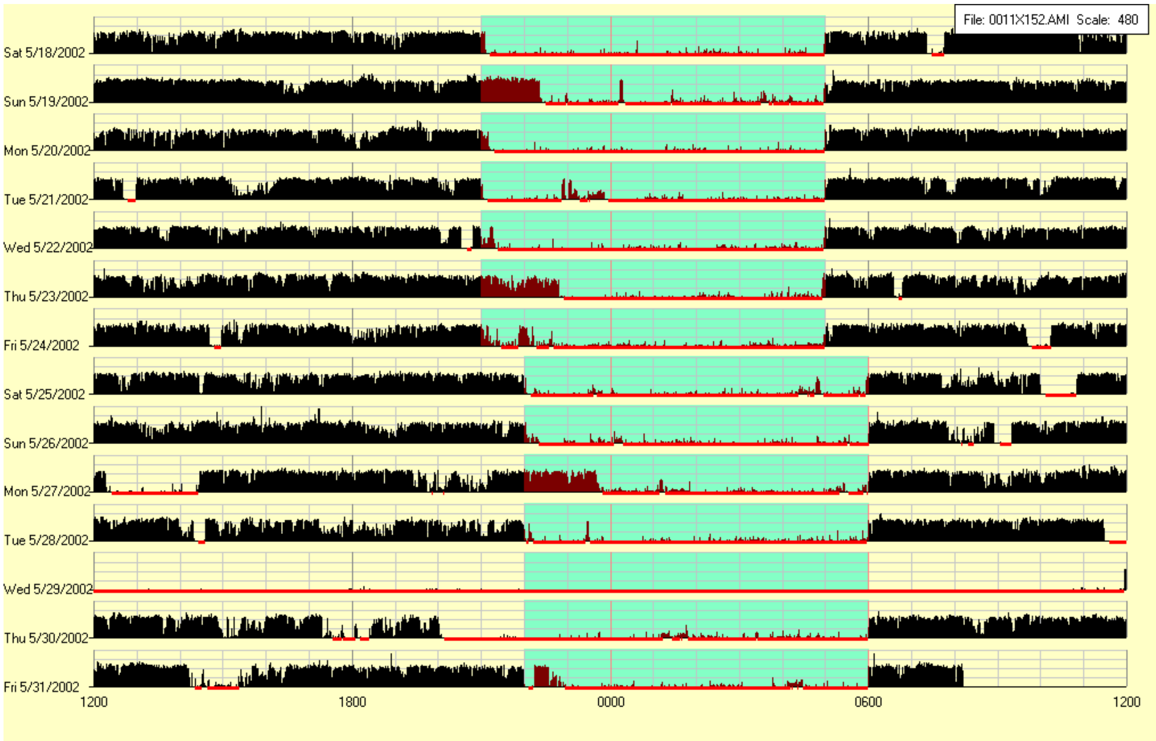
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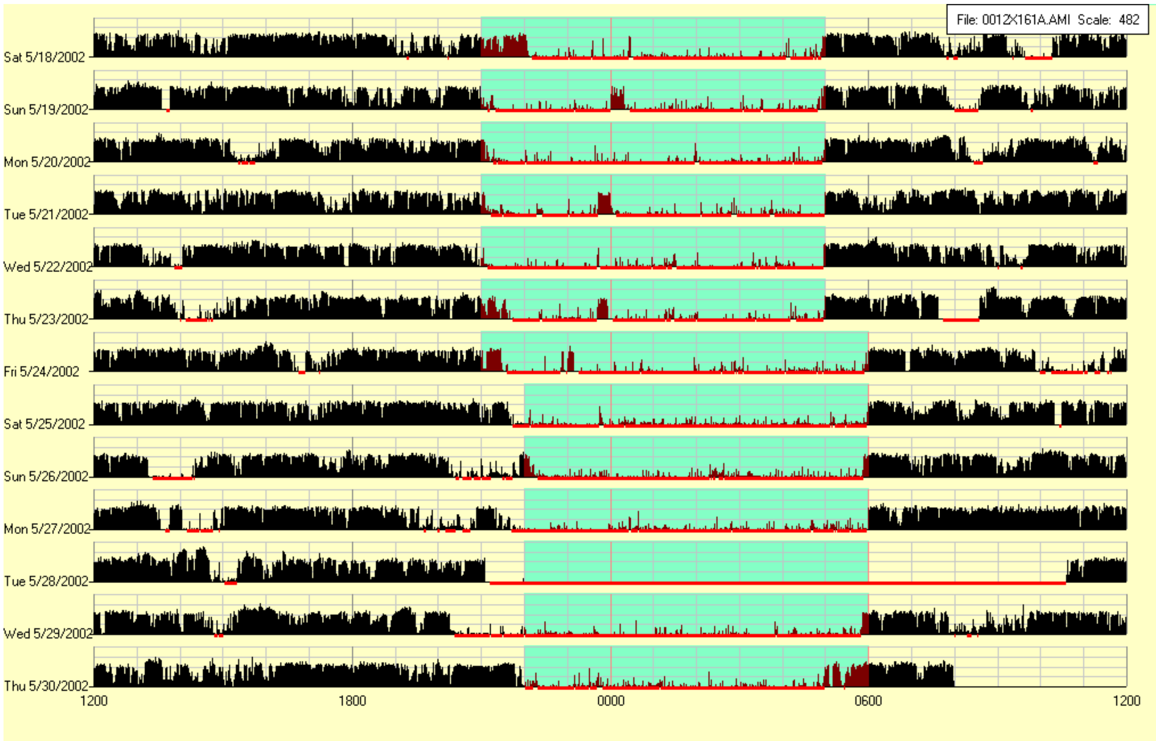
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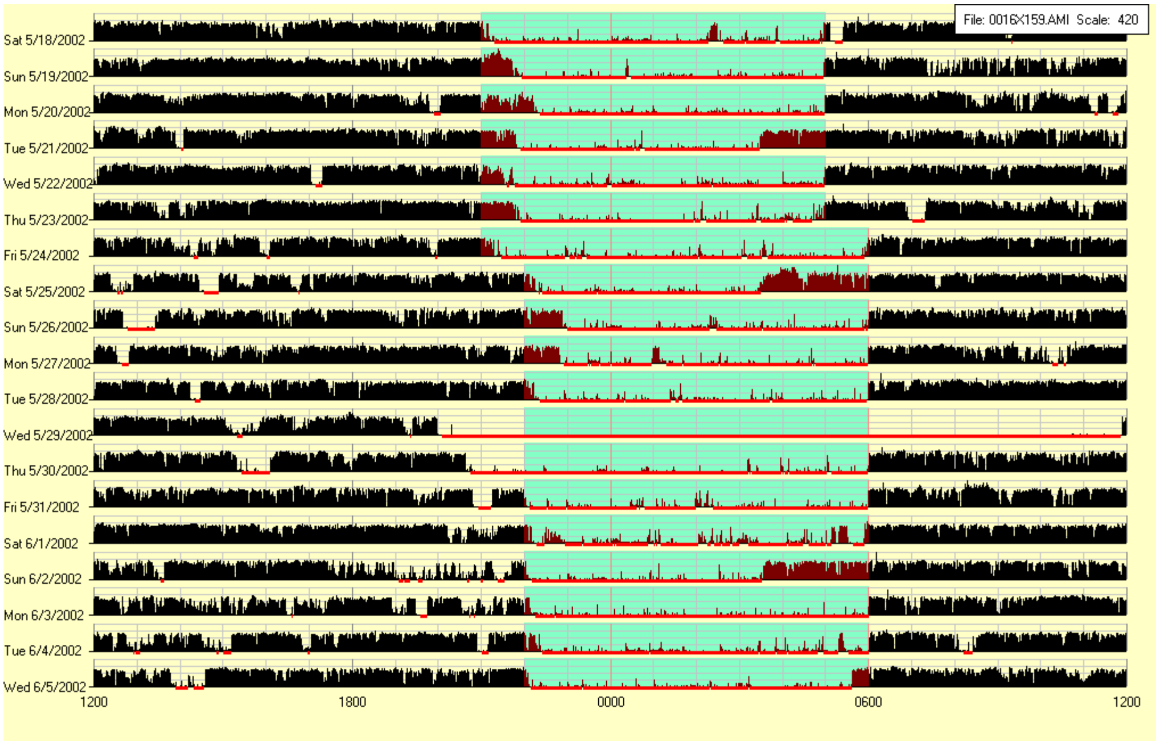
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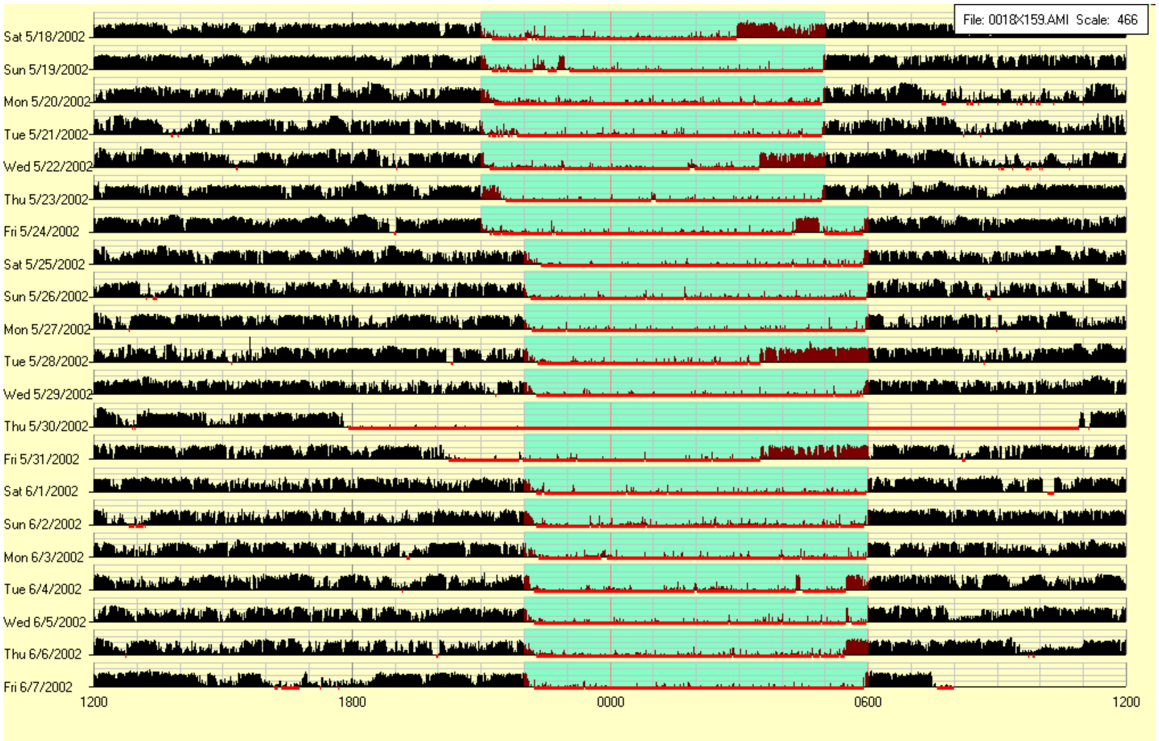
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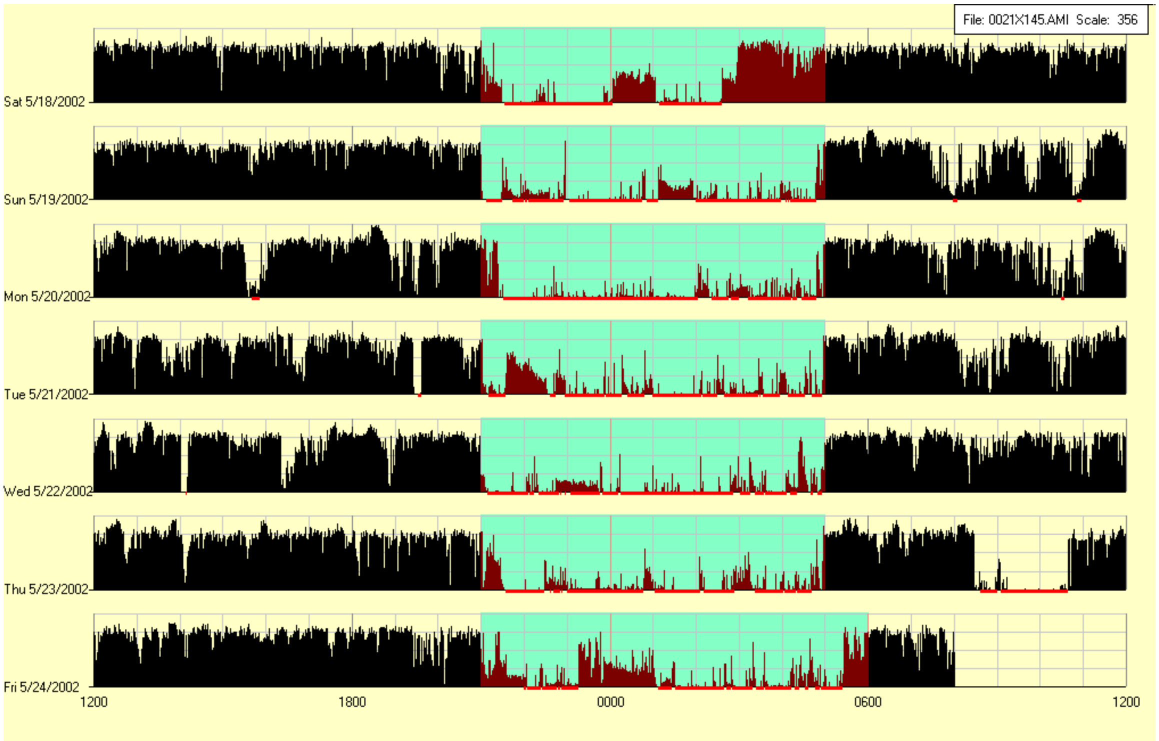
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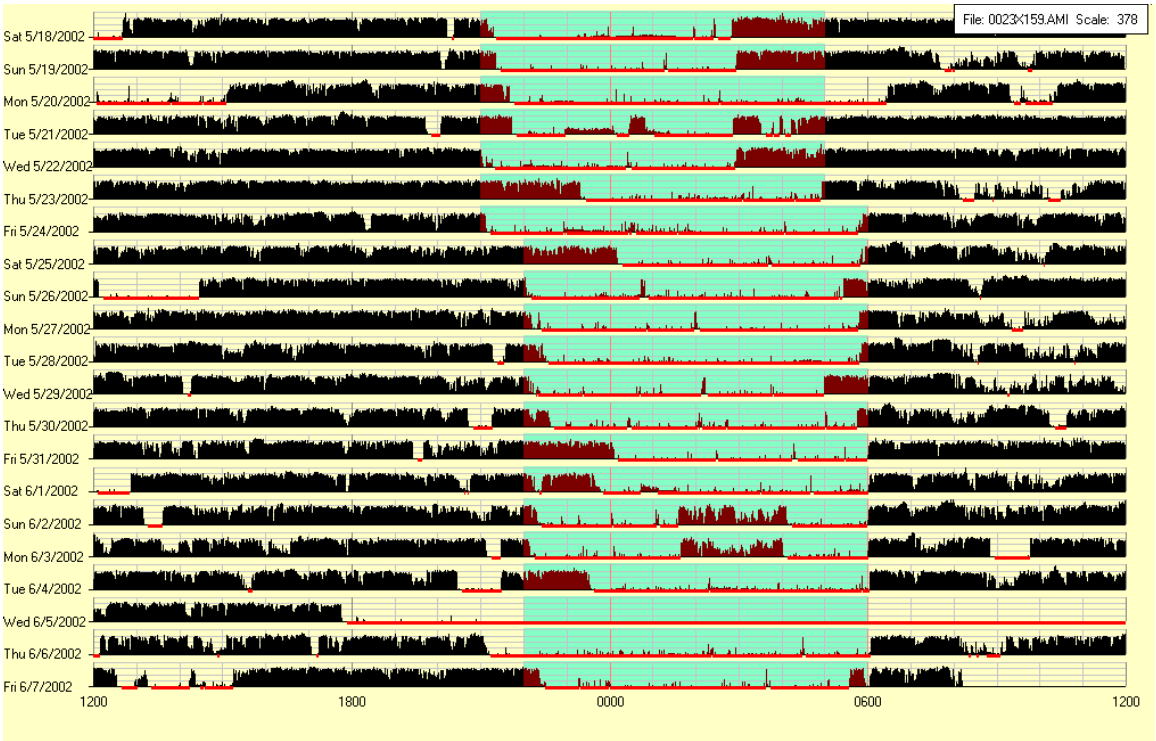
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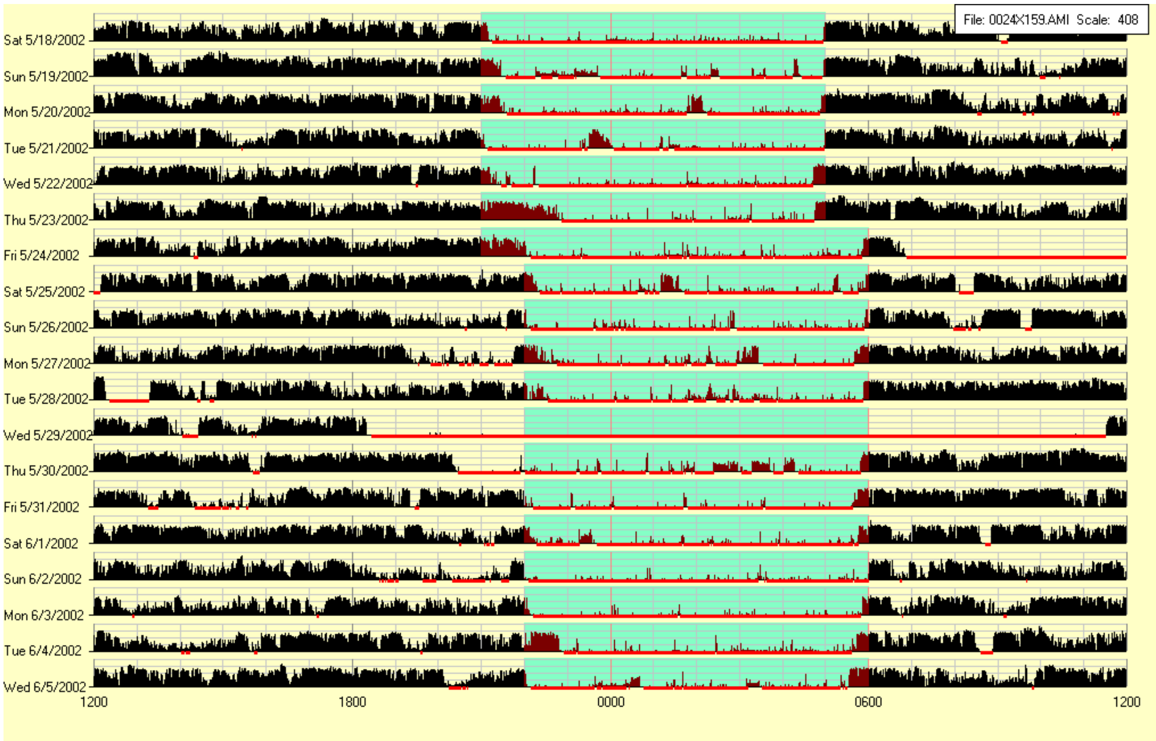
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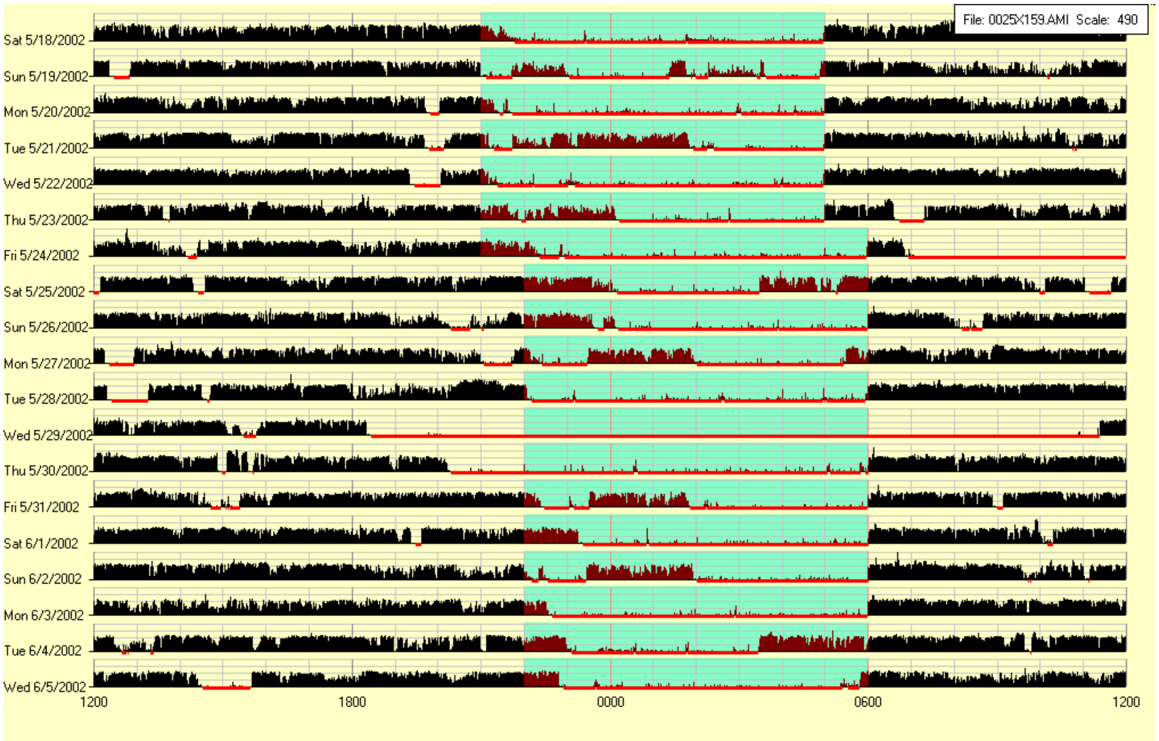
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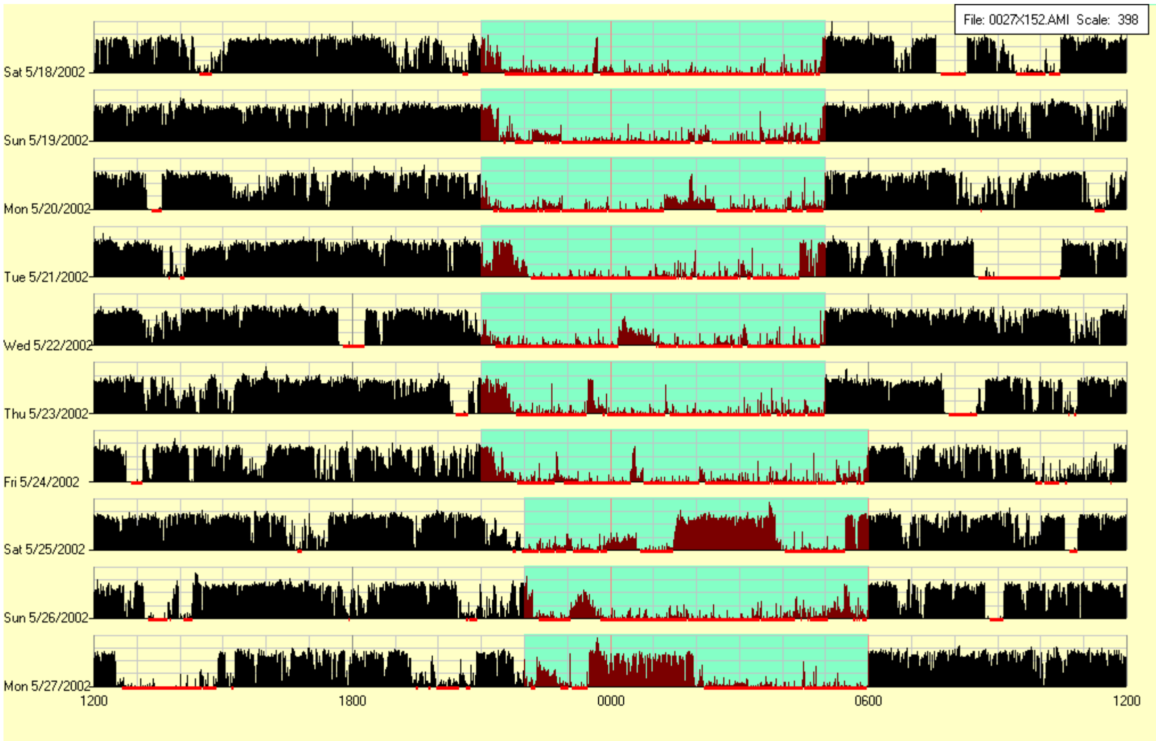
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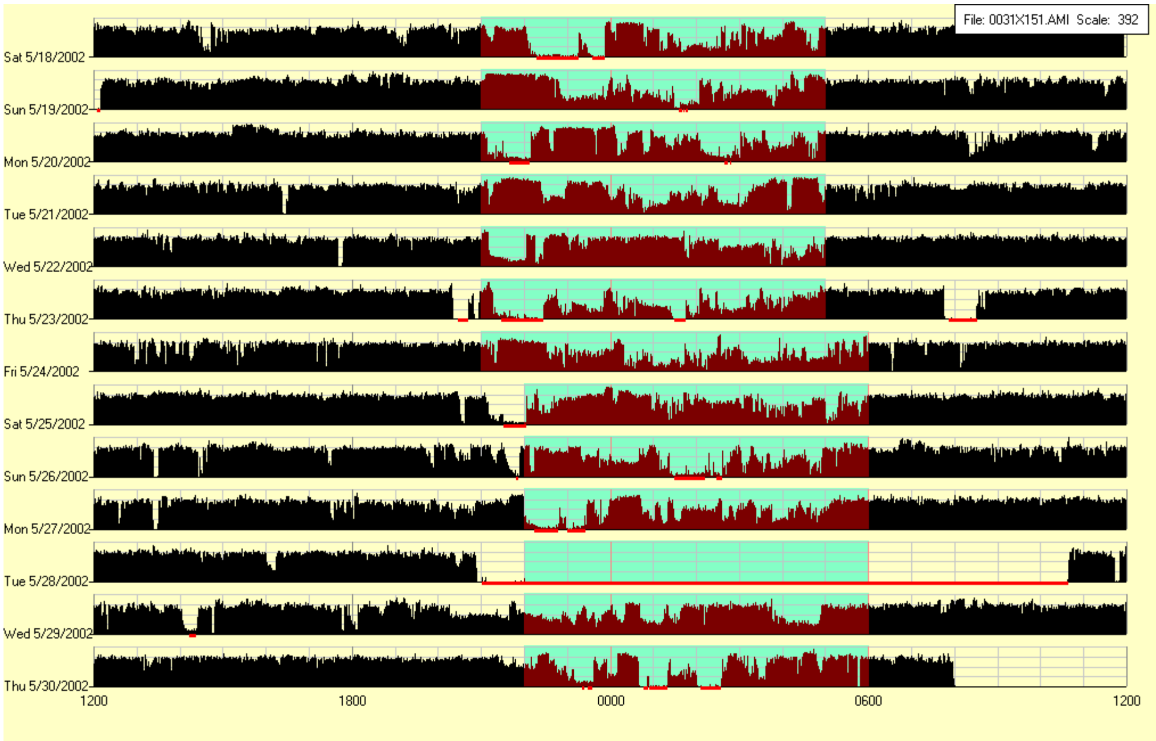
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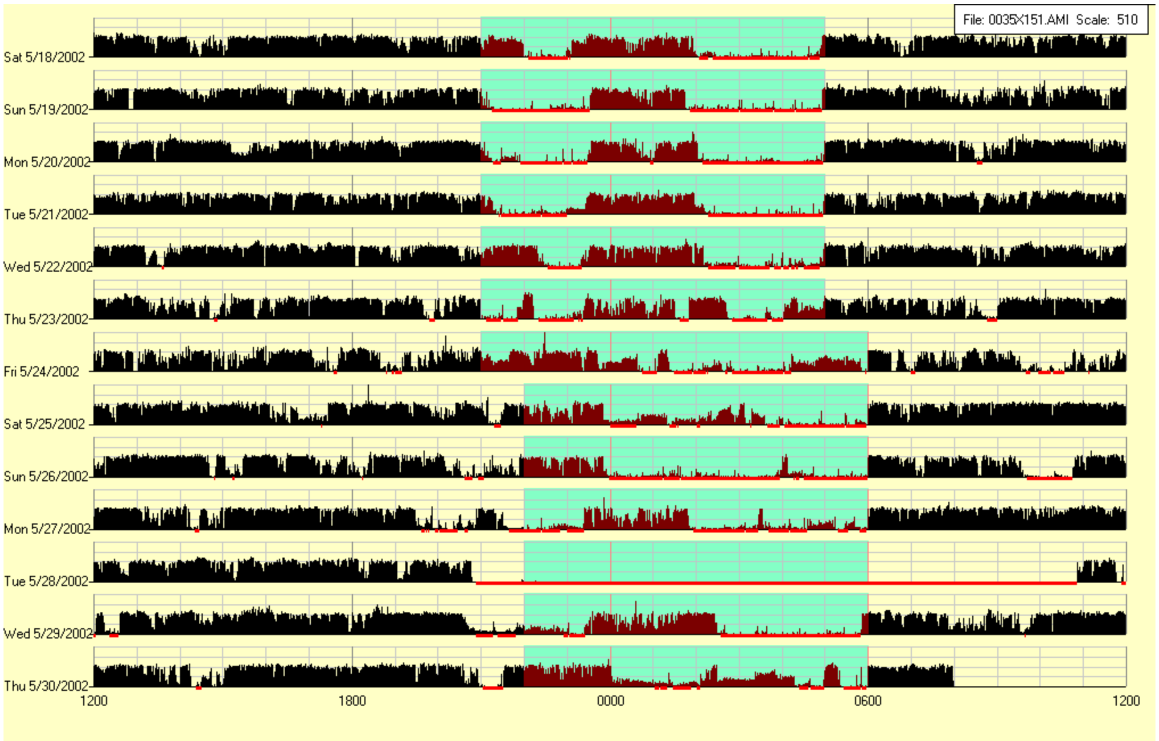
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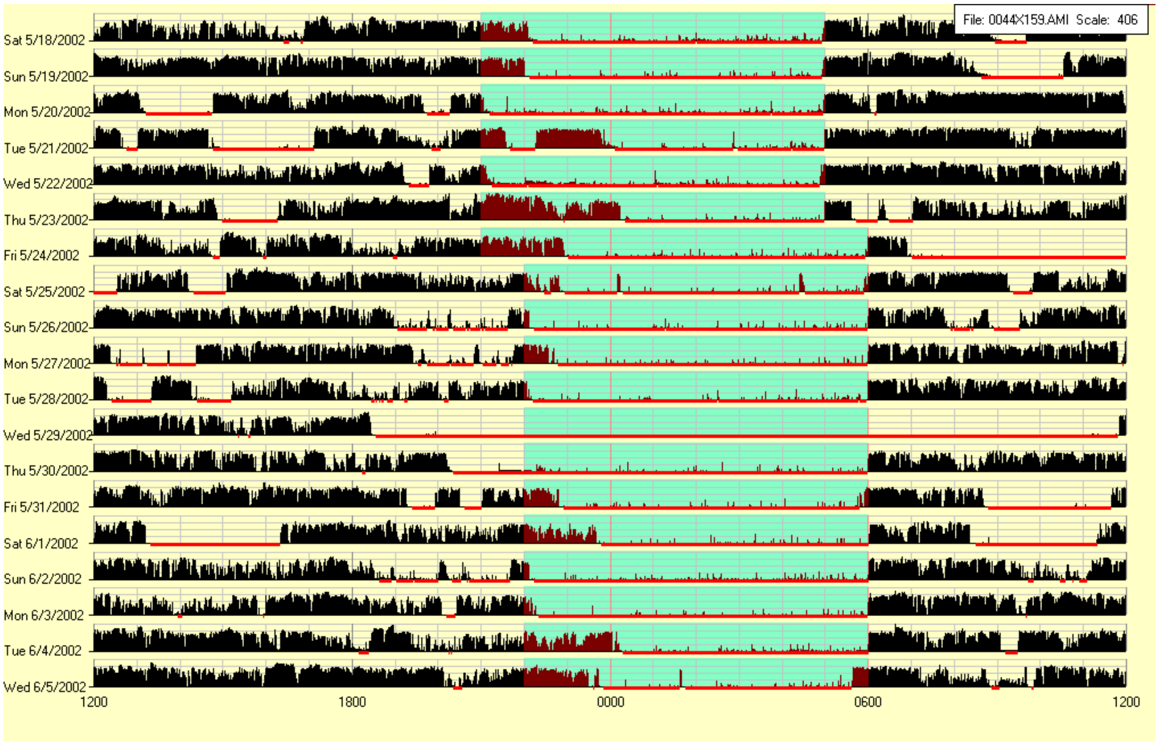
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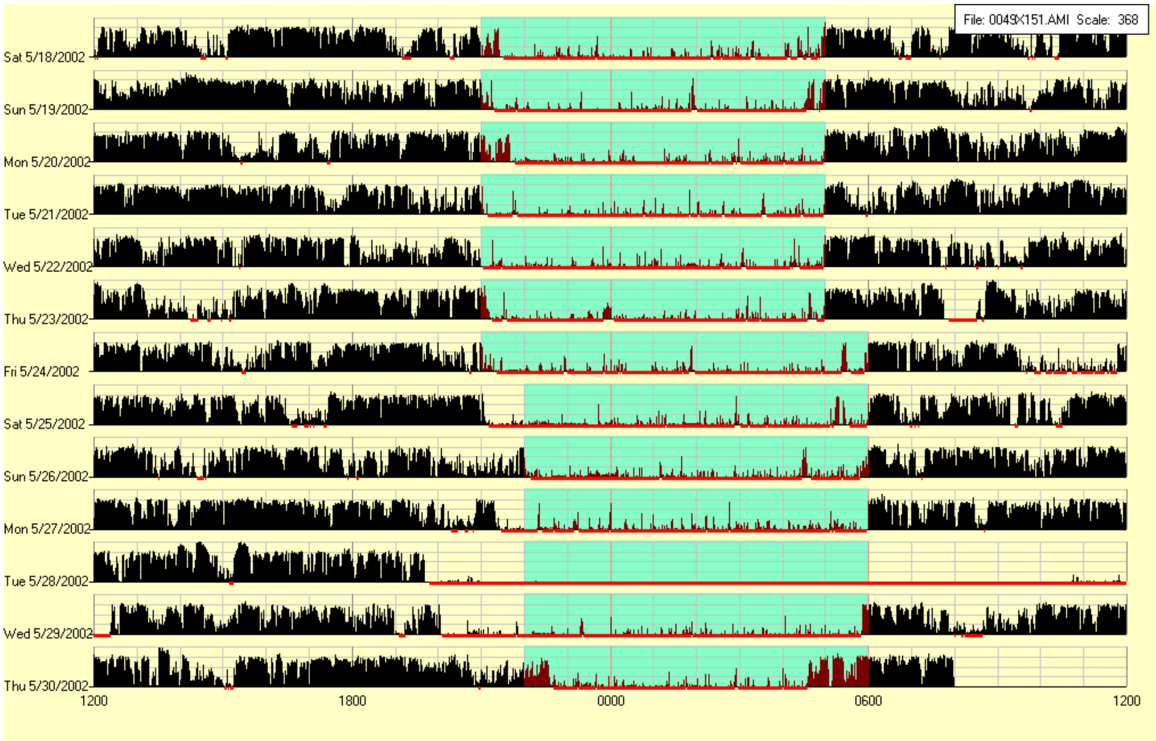
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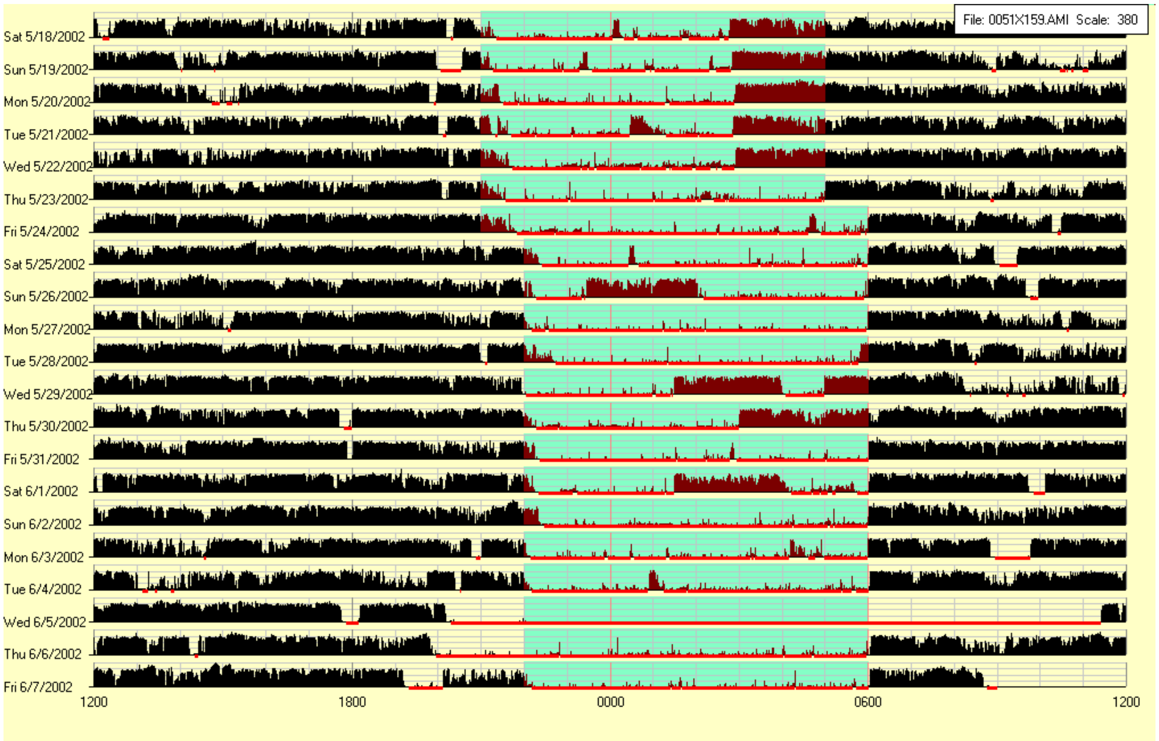
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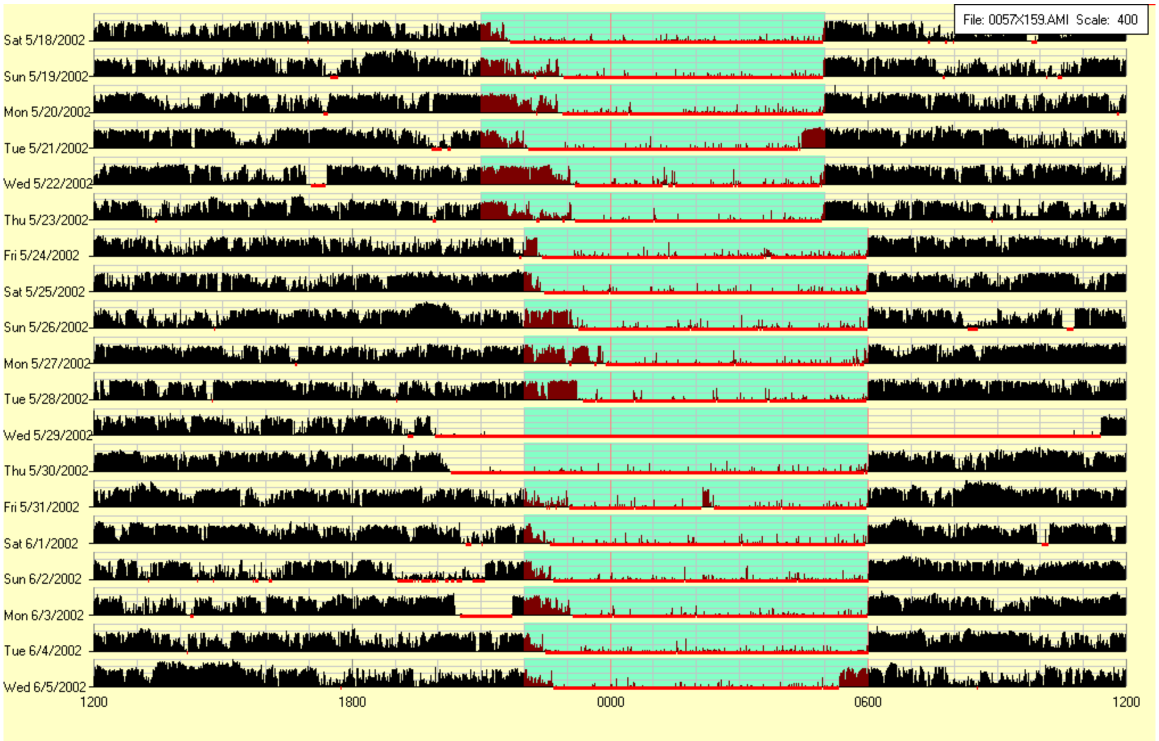
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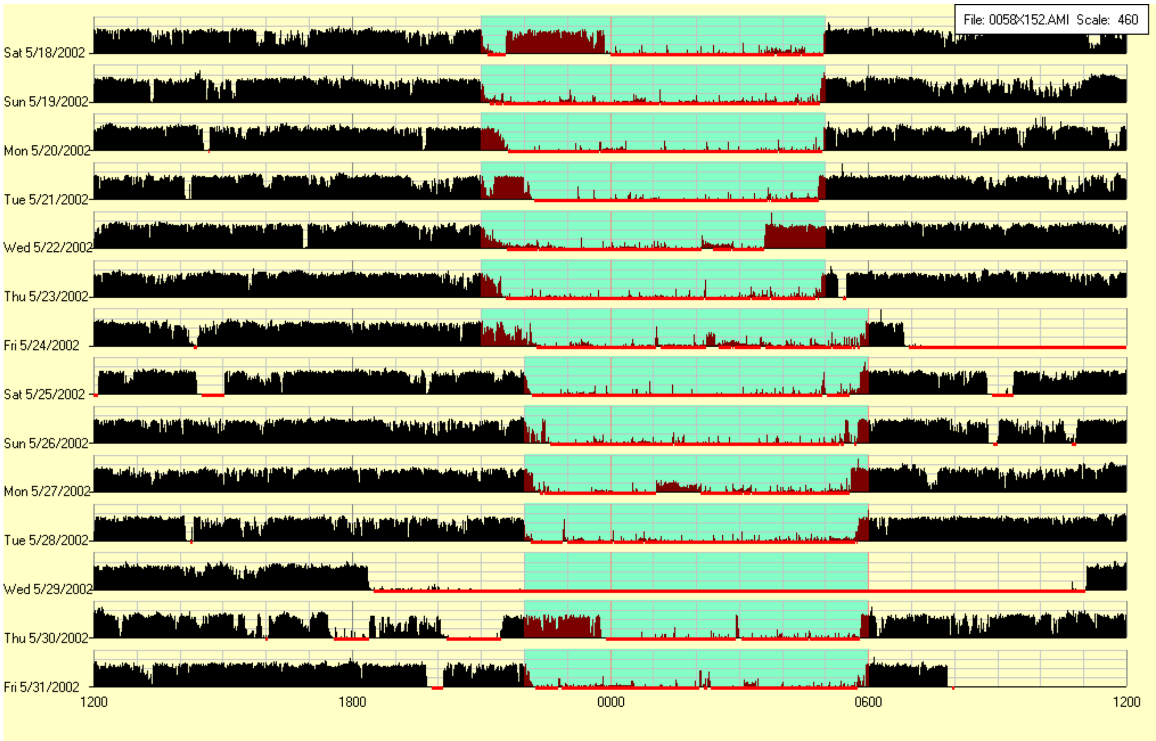
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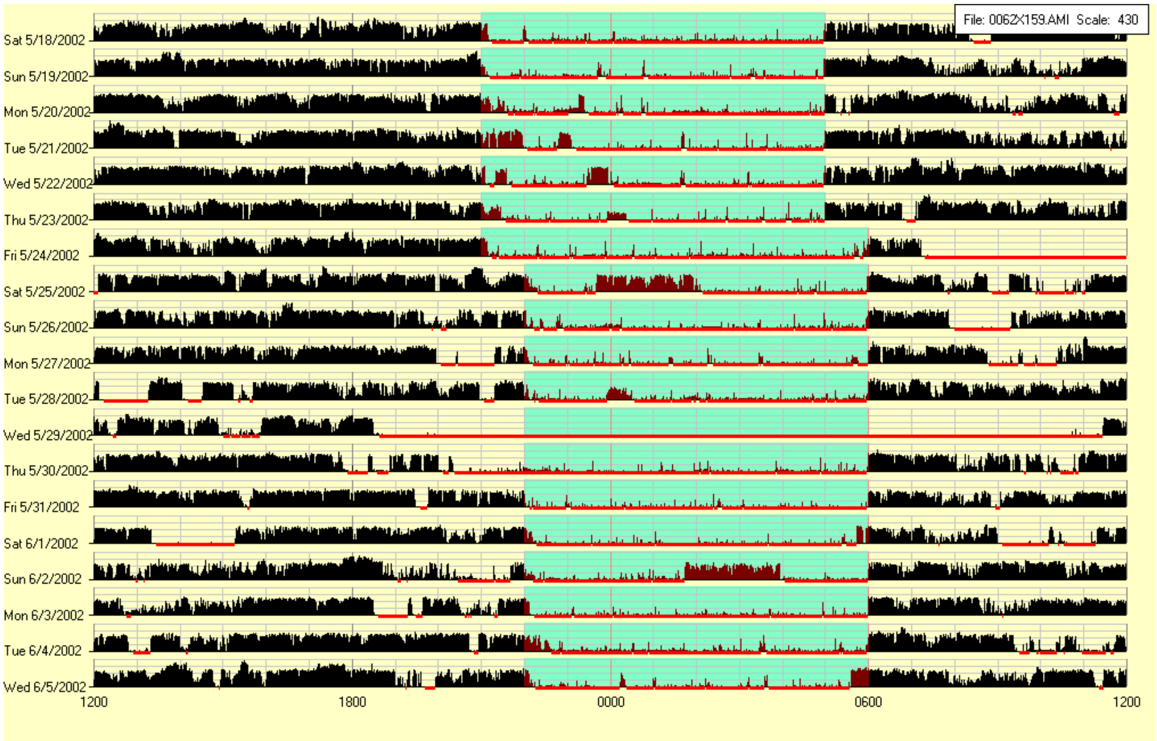

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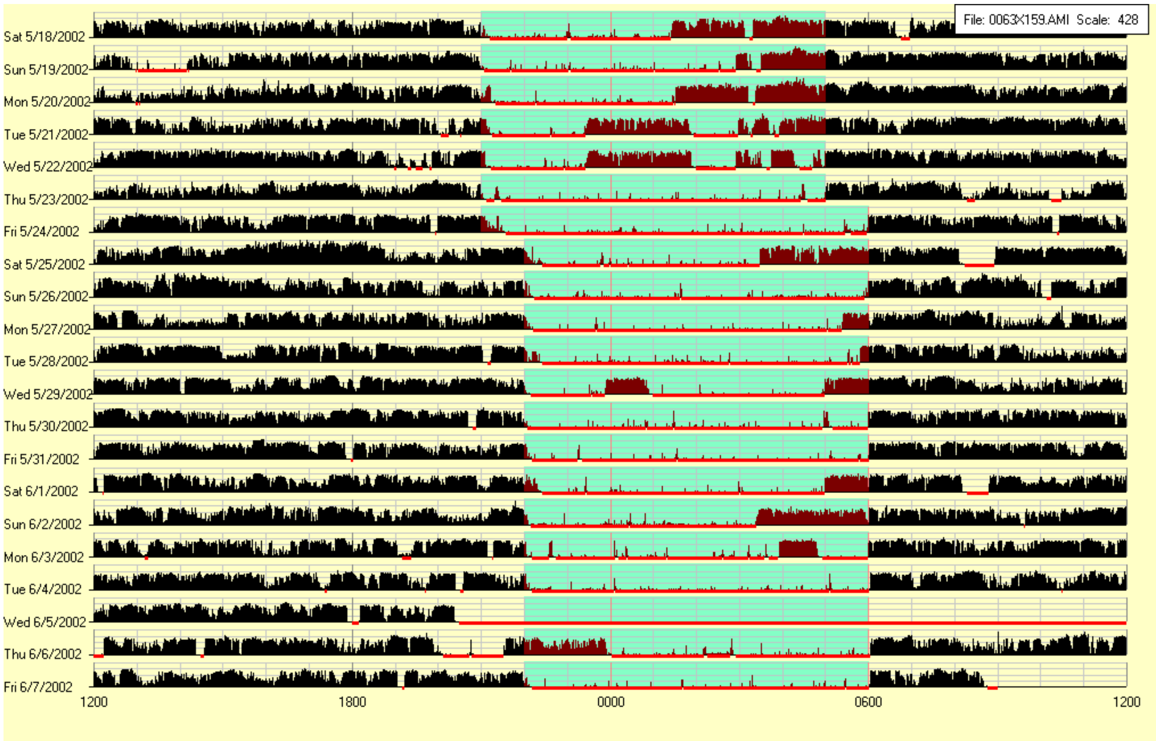
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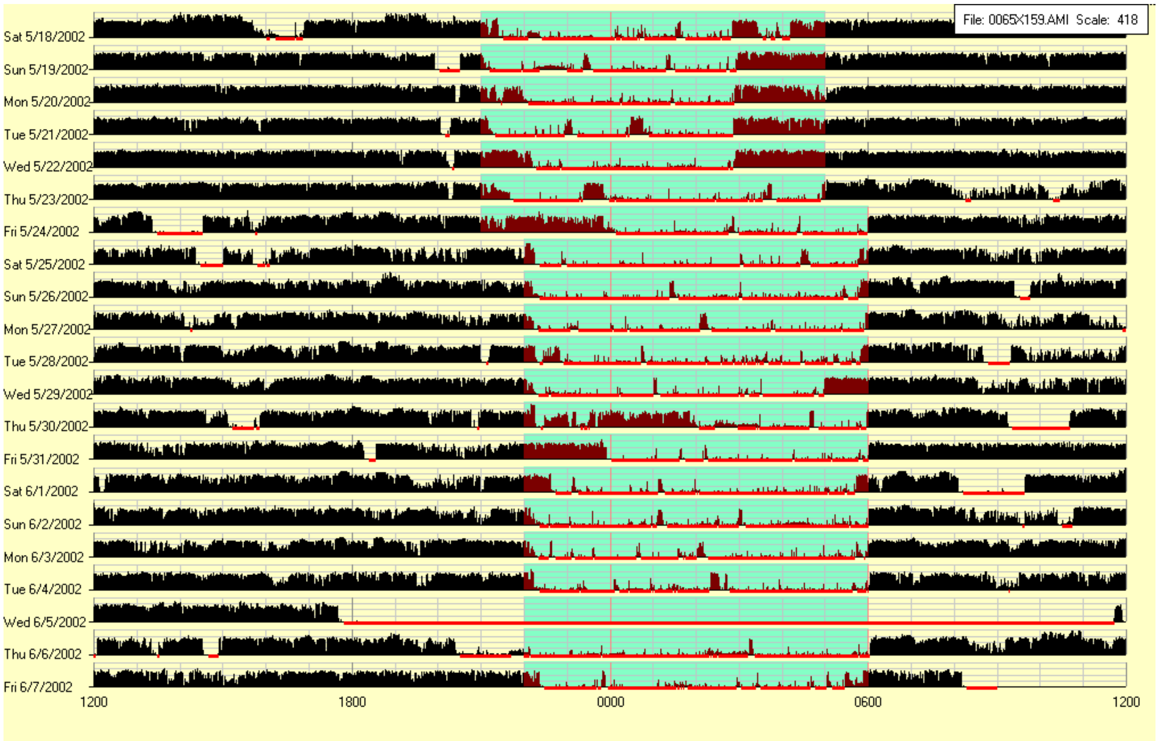
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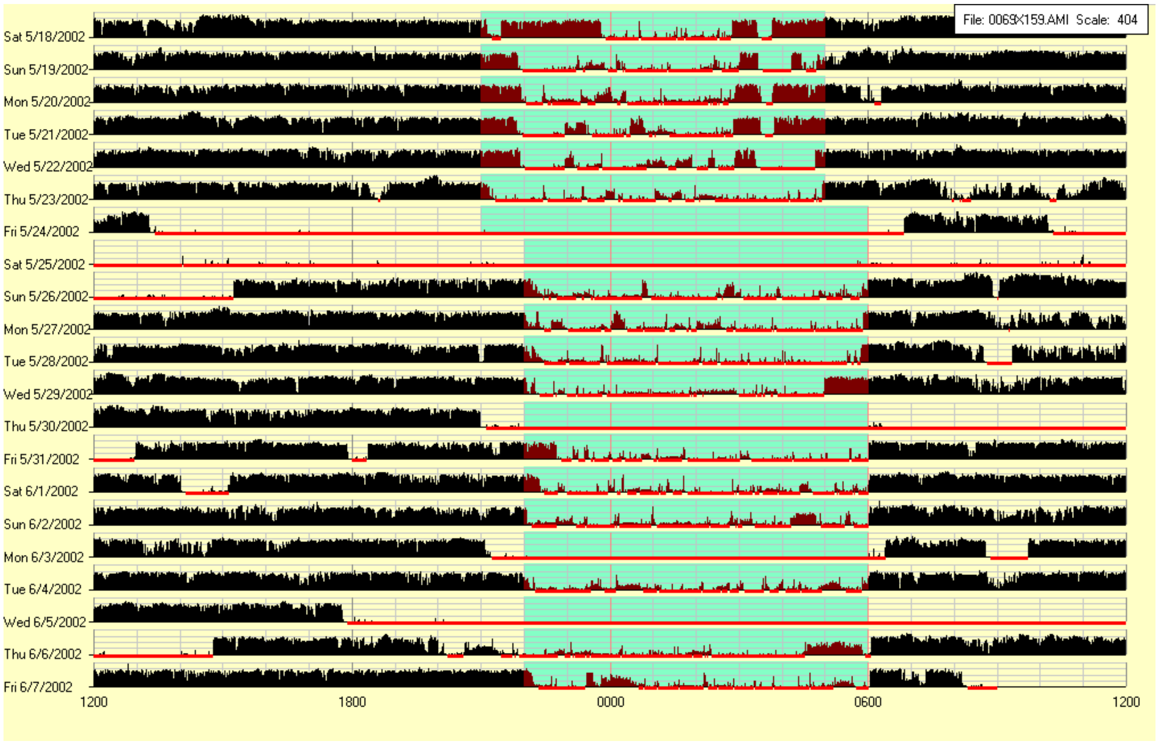
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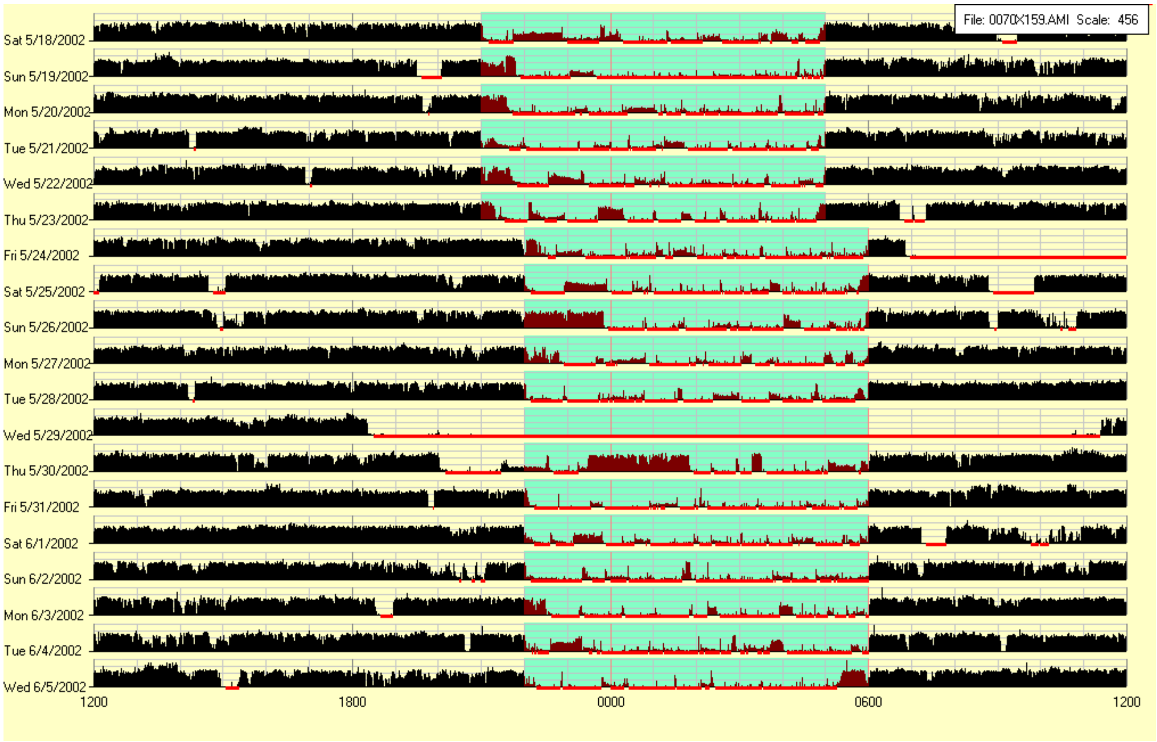
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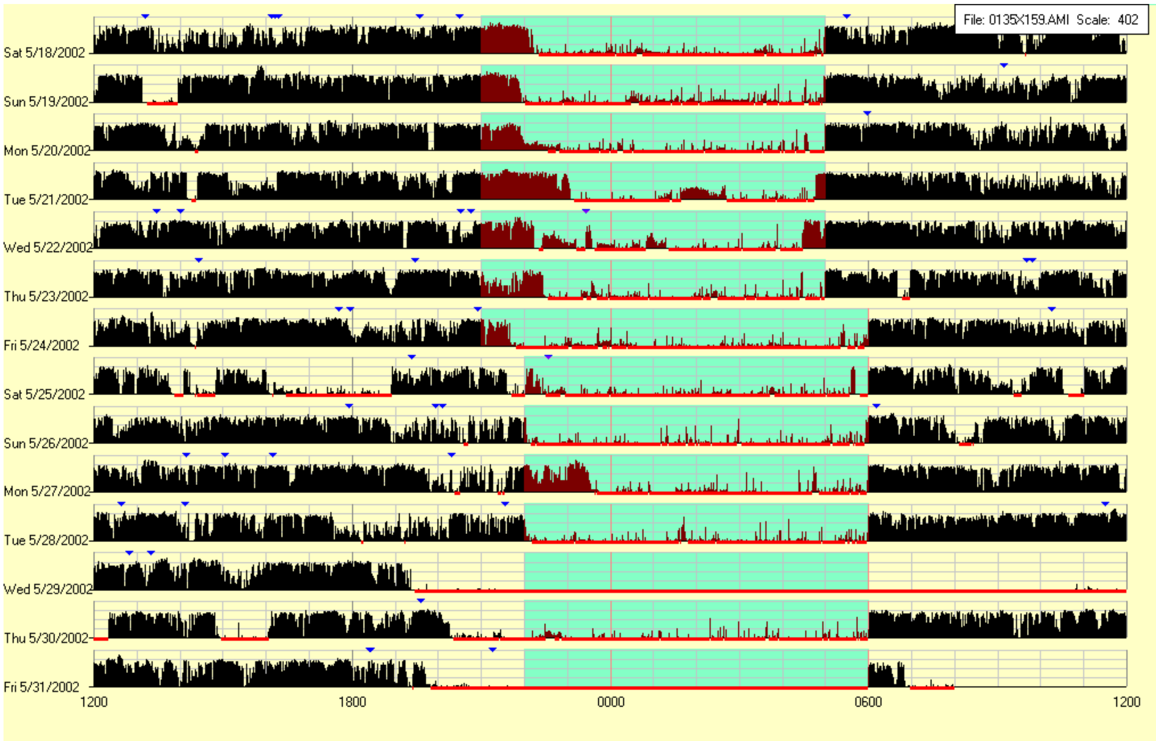
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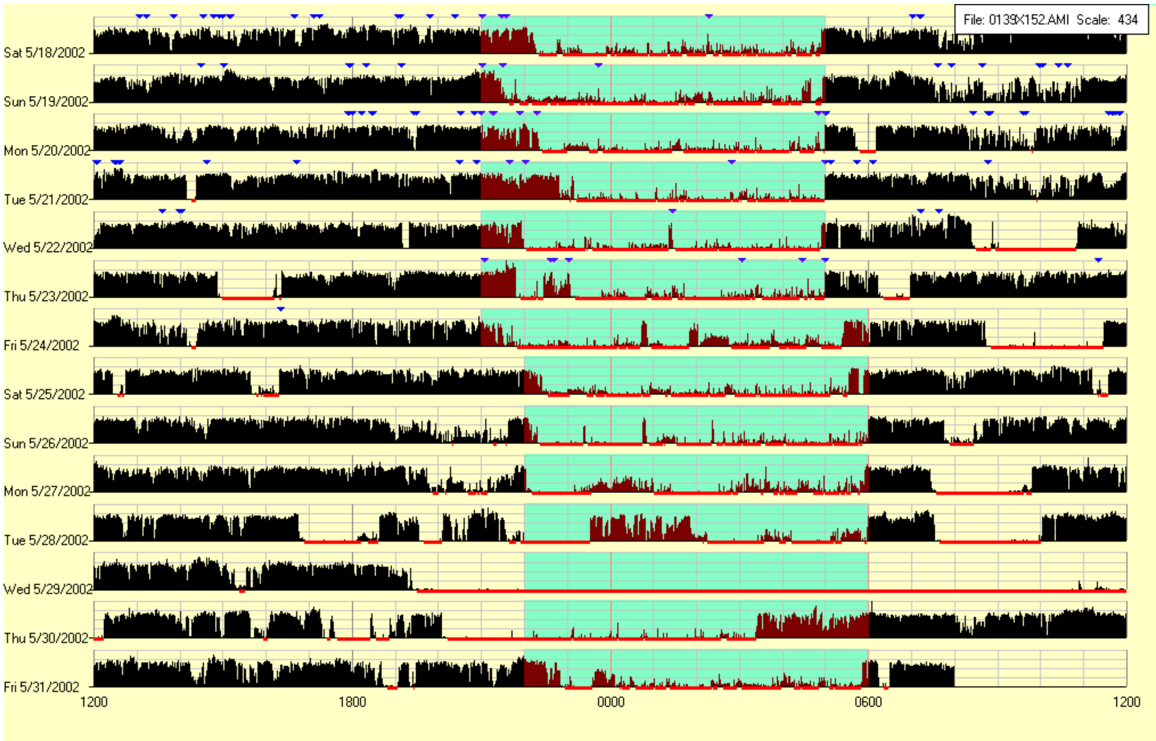
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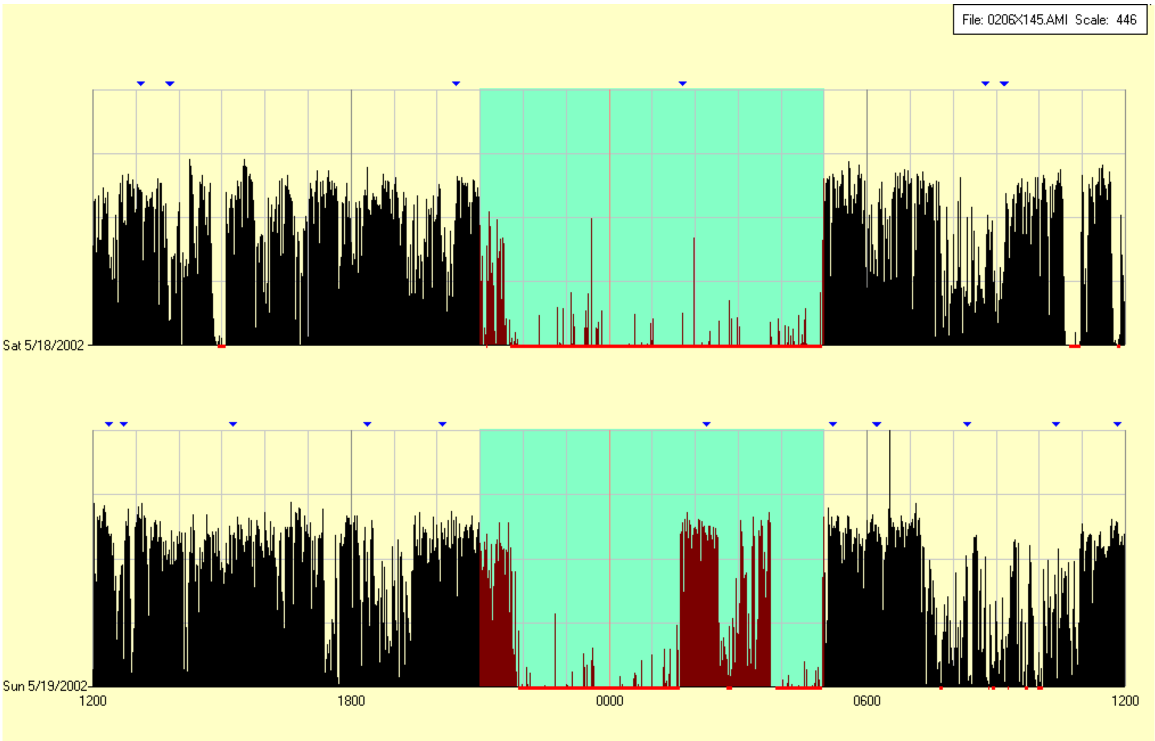
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# APPENDIX B. SAMPLE PARTICIPANT CONSENT FORM

1. **Introduction.** You are invited to participate in a study of fatigue and circadian rhythms. With information gathered from you and other participants, we hope to gain insight into how human performance varies with sleep cycles. We ask you to read and sign this form indicating that you agree to be in the study. Please ask any questions you may have before signing.

2. **Background Information.** The Naval Postgraduate School Navy Fatigue Countermeasures Research Group is conducting this study.

3. **Procedures.** If you agree to participate in this study, the researcher will explain the tasks in detail. Data will be collected using an actigraph which measures your activity level. You may be expected to fill out a survey that describes your normal and preferred sleep habits, to measure and record your oral temperature and to record an estimation of your subjective feeling of "sleepiness". Additional data may include simple performance measures of reaction time, which could take approximately 5 minutes to complete.

4. **Risks and Benefits.** This research involves no risks or discomforts other than those experienced when having oral (under the tongue) temperatures taken and wearing a wristwatch. There are no direct benefits to you for your participation. The indirect benefits are that you will be contributing to current research in human fatigue.

5. **Compensation.** No tangible reward will be given. A copy of the results will be available to you at the conclusion of the study.

6. **Confidentiality.** The records of this study will be kept confidential. No information will be publicly accessible which could identify you as a participant.

7. **Voluntary Nature of the Study.** If you agree to participate, you are free to withdraw from the study at any time without prejudice. You will be provided a copy of this form for your records.

8. **Points of Contact.** If you have any further questions or comments after the completion of the study, you may contact the research supervisor, Dr. Nita Lewis Miller (831) 656-2281 or email at nlmiller@nps.navy.mil.

9. **Statement of Consent.** I have read the above information. I have asked all questions and have had my questions answered. I agree to participate in this study.

---------------------------------------------- --------------------------
Participant's Signature Date

---------------------------------------------- --------------------------
Researcher's Signature Date

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# APPENDIX C. SAMPLE PRIVACY ACT FORM

1. Authority: Naval Instruction

2. Purpose: Activity levels, oral temperatures, subjective fatigue, and simple human performance data will be collected to enhance knowledge of fatigue and sleep patterns of USN personnel.

3. Use: Data will be used for statistical analysis by the Departments of the Navy and Defense, and other U.S. Government agencies, provided this use is compatible with the purpose for which the information was collected. Use of the information may be granted to legitimate non-government agencies or individuals by the Naval Postgraduate School in accordance with the provisions of the Freedom of Information Act.

4. Disclosure/Confidentiality:

    a. I have been assured that my privacy will be safeguarded. I will be assigned a control or code number, which thereafter will be the only identifying entry on any of the research records. The Principal Investigator will maintain the cross-reference between name and control number. It will be decoded only when beneficial to me or if some circumstances, which are not apparent at this time, would make it clear that decoding would enhance the value of the research data. In all cases, the provisions of the Privacy Act Statement will be honored.

    b. I understand that a record of the information contained in this Consent Statement or derived from the experiment described herein will be retained permanently at the Naval Postgraduate School or by higher authority. I voluntarily agree to its disclosure to agencies or individuals indicated in paragraph 3 and I have been informed that failure to agree to such disclosure may negate the purpose for which the experiment was conducted.

    c. I also understand that disclosure of the requested information, including my Social Security Number, is voluntary.

________________________________________________
Signature of Volunteer Name, Grade/Rank (if applicable)

________________________________________________
DOB SSN Date

________________________________________________
Signature of Witness Date

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# APPENDIX D. SAMPLE MINIMAL RISK FORM

VOLUNTARY CONSENT TO BE A RESEARCH PARTICIPANT IN:
Circadian Rhythms, Sleep Patterns and Human Performance

1. I have read, understood and been provided "Information for Participants" that provides the details of the below acknowledgments.
2. I understand that this project involves research. An explanation of the purposes of the research, a description of procedures to be used, identification of experimental procedures, and the duration of my participation have been provided to me.
3. I understand that this project does not involve more than minimal risk. I have been informed of any reasonably foreseeable risks or discomforts to me.
4. I have been informed of any benefits to me or to others that may reasonably be expected from the research.
5. I have signed a statement describing the extent to which confidentiality of records identifying me will be maintained.
6. I have been informed of any compensation and/or medical treatments available if injury occurs and is so, what they consist of, or where further information may be obtained.
7. I understand that my participation in this project is voluntary; refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I also understand that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.
8. I understand that the individual to contact should I need answers to pertinent questions about the research is Professor Nita Lewis Miller, Principal Investigator, and about my rights as a research participant or concerning a research related injury is the Operations Research Department Chairman. A full and responsive discussion of the elements of this project and my consent has taken place.

Medical Monitor: Flight Surgeon, Naval Postgraduate School

Signature of Principal Investigator Date

Signature of Volunteer Date

Signature of Witness Date

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